<u>STANDARDS OVERVIEW ACTIVITY:</u> ***What Indiana's students & teachers need to know and be able to do in <u>Science.</u>***

	Kindergarten Standard	Teacher Preparation Standard
<u>Standard 1. The Nature of Science and Technology</u> **Students are actively engaged in beginning to explore how their world works. They explore, observe, ask questions, discuss observations and seek answers.**	**1.1 Scientific Inquiry** Þ Raise questions about the natural world. **1.2 The Scientific Enterprise** ⇒ Begin to demonstrate that everyone can do science. .	Standard 1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that makes these aspects of science meaningful for the student. (see detailed bullet points under 1)Knowledge: Central Concepts, 2)Knowledge: Nature of Science, and 3)Knowledge: Tools of Inquiry) *Note: Teachers at this level have in depth preparation in one of the content areas of Appendix C. Alignment has been done using excerpts from the Appendices which apply to all teachers of science and which are referred to in the Comprehensive Standards Document.*
<u>Standard 2. Scientific Thinking</u> **Students use numbers, pictures, and words when observing and communicating to help them begin to answer their questions about the world.**	**2.1 Computation and Estimation** Þ Use whole numbers (0, 1, 2, 3, etc.), up to 10, in counting, identifying, sorting, and describing objects and experiences. **2.2 Communication** Þ Draw pictures and write words to describe objects and experiences.	Appendix F: Estimation and Computation Skills • including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. • providing experience with basic number skills and computations in meaningful contexts. Appendix F: Communication Skills ▪ providing opportunities to communicate ideas and share information with accuracy and clarity and to read and listen with understanding.
<u>Standard 3. The Physical Setting</u> **Students investigate, describe, and discuss their natural surroundings. They begin to question why things move.**	**3.1 Matter and Energy** Þ Describe objects in terms of the materials they are made of, such as clay, cloth, paper, etc. **3.2 Forces of Nature** Þ Investigate that things move in different ways, such as fast, slow, etc.	Appendix B: Systems Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world.

<u>Standard 4. The Living Environment</u> **Students ask questions about a variety of living things and everyday events that can be answered through shared environment.**	**4.1 Diversity of Life** Þ Give examples of plants and animals. Þ Observe plants and animals, describing how they are alike and how they are different in the way they look and in the things they do.	Appendix B: Systems, Order and Organization Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions.
<u>Standard 5. The Mathematical World</u> **Students use shapes to compare objects and they begin to recognize patterns.**	**5.1 Shapes and Symbolic Relationships** Þ Use shapes, such as circles, squares, rectangles, and triangles, to describe different objects.	Appendix B: Forms and Function Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form. The understanding of form and function applies to different levels of organization. Students should be able to explain function by referring to form, and to explain form by referring to function.
<u>Standard 6. Common Themes</u> **Students begin to understand how things are similar and how they are different. They look for ways to distinguish between different objects by observation.**	**6.1 Models and Scale** Þ Describe an object by saying how it is similar to or different from another object.	Appendix B: Evidence, Models and Explanation Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

STANDARDS OVERVIEW ACTIVITY: *What Indiana's students & teachers need to know and be able to do in Science.*

	1st Grade Student Standard	Teacher Preparation Standard
Standard 1. The Nature of Science and Technology **Students are actively engaged in exploring how the world works. They explore, observe, count, collect, measure, compare, and ask questions. They discuss observations and use tools to seek answers and solve problems. They share their findings.**	**1.1 Scientific Inquiry** Þ Observe, describe, draw, and sort objects carefully to learn about them. Þ Investigate and make observations to seek answers to questions about the world, such as "In what ways do animals move?" **1.2 The Scientific Enterprise** Þ Recognize that and demonstrate how people can learn much about plants and animals by observing them closely over a period of time. Recognize also that care must be taken to know the needs of living things and how to provide for them. **1.3 Technology and Science** Þ Use tools, such as rulers and magnifiers, to investigate the world and make observations.	Standard 1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that makes these aspects of science meaningful for the student. (see detailed bullet points under 1)Knowledge: Central Concepts, 2)Knowledge: Nature of Science, and 3)Knowledge: Tools of Inquiry). Standard 4: The teacher of science understands and uses a variety of instructional strategies to encourage students' development of conceptual understanding, inquiry skills, and scientific habits of mind. (see detailed Bullet points under Knowledge) *Note: Teachers at this level have in depth preparation in one of the content areas of Appendix C. Alignment has been done using excerpts from the Appendices which apply to all teachers of science and which are referred to in the Comprehensive Standards Document.*
Standard 2. Scientific Thinking **Students begin to find answers to their questions about the world by using measurements, estimation, and observation as well as working with materials. They communicate with others through numbers, words and drawings.**	**2.1 Computation and Estimation** Þ Use whole numbers, (0, 1, 2, 3, etc.) up to 100, in counting, identifying, measuring, and describing objects and experiences. Þ Use sums and differences of single-digit numbers in investigations and judge the reasonableness of the answers. Þ Explain to other students how to go about solving numerical problems. **2.2 Manipulation and Observation** Þ Measure the length of objects having straight edges in inches, centimeters, or non-standard units. Þ Demonstrate that magnifiers help people see things they could not see without them.	Appendix F: Estimation and Computation Skills • including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. • providing experience with basic number skills and computations in meaningful contexts. Appendix F: Manipulation and Observation Skills • providing opportunities to handle common materials and tools for dealing with household and everyday technologies for making careful observations, and for handling information Appendix F: Communication Skills • providing opportunities to communicate ideas and share information with accuracy and clarity and to read and listen with understanding.

	2.3 Communication Skills Þ Describe and compare objects in terms of number, shape, texture, size, weight, color, and motion. Þ Write brief informational descriptions of a real object, person, place, or event using information from observations.	\
<u>Standard 3. The Physical Setting</u> **Students investigate, describe, and discuss their natural surroundings. They question why things move and change.**	**3.1 The Earth and the Processes that Shape It** Þ Recognize and explain that water can be a liquid or a solid and can go back and forth from one form to the other. Investigate by observing that if water is turned into ice and then the ice is allowed to melt, the amount of water is the same as it was before freezing. Þ Investigate by observing and then describe that water left in an open container disappears, but water in a closed container does not disappear. **3.2 Matter and Energy** Þ Investigate by observing and also measuring that the sun warms the land, air, and water. **3.3 Forces of Nature** Þ Investigate by observing, and then describe how things move in many different ways, such as straight, zigzag, round-and-round, and back-and-forth. Þ Recognize that and demonstrate how things near the Earth fall to the ground unless something holds them up.	Appendix B: Systems Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix F: Critical Response Skills ▪ allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. ▪ allowing students to apply those same critical skills to their own observations, arguments, and conclusions.

<u>Standard 4. The Living Environment</u> **Students ask questions about a variety of living things and everyday events that can be answered through observations. They become aware of plant and animal interaction. They consider things and processes that plants and animals need to stay alive.**	**4.1 Diversity of Life** Þ Identify when stories give attributes to plants and animals, such as the ability to speak, that they really do not have. Þ Observe and describe that there can be differences, such as size or markings, among the individuals within one kind of plant or animal group. **4.2 Interdependence of Life** Þ Observe and explain that animals eat plants or other animals for food. Þ Explain that most living things need water, food, and air.	Appendix B: Systems, Order and Organization Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions.
<u>Standard 5. The Mathematical World</u> **Students apply mathematics in scientific contexts. They begin to use numbers for computing, estimating, naming, measuring, and communicating specific information. They make picture graphs and recognize patterns.**	**5.1 Numbers** Þ Use numbers, up to 10, to place objects in order, such as first, second, and third, and to name them, such as bus numbers or phone numbers. Þ Make and use simple picture graphs to tell about observations. **5.2 Shapes and Symbolic Relationships** Þ Observe and describe similar patterns, such as shapes, designs, and events that may show up in nature, like honeycombs, sunflowers, or shells. See similar patterns in the things people make like quilts, baskets, or pottery.	Appendix B: Forms and Function Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form. The understanding of form and function applies to different levels of organization. Students should be able to explain function by referring to form, and to explain form by referring to function. Appendix F: Estimation and Computation Skills Providing experience with basic number skills and computations in meaningful contexts.

<u>Standard 6. Common Themes</u> **Students begin to understand how things are similar and how they are different. They look for what changes and what does not change and make comparisons.**	**6.1 Models and Scale** Þ Observe and describe that models, such as toys, are like the real things in some ways but different in others. **6.2 Constancy and Change** Þ Observe that and describe how certain things change in some ways and stay the same in others, such as in their color, size, and weight.	Appendix B: Evidence, Models and Explanation Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations. Appendix B: Constancy, Change and Measurement Although most things are in the process of becoming different--changing--some properties of objects and processes are characterized by constancy, including the speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles.

STANDARDS OVERVIEW ACTIVITY: *What Indiana's students & teachers need to know and be able to do in Science.*

	2nd Grade Student Standard	Teacher Preparation Standard
Standard 1. The Nature of Science and Technology **Students are actively engaged in exploring how the world works. They explore, observe, count collect, measure, compare and ask questions. They discuss observations and use tools to seek answers and solve problems. They share their findings.**	**1.1.Scientific Inquiry** Þ Manipulate an object to gain additional information about it. Þ Use tools, such as thermometers, magnifiers, rulers, or balances, to gain more information about objects. Þ Describe, both in writing and verbally, objects as accurately as possible and compare observations with those of other people. Þ Make new observations when there is disagreement among initial observations. **1.1 The Scientific Enterprise** Þ Demonstrate the ability to work with a team but still reach and communicate one's own conclusions about findings. **1.2 Technology and Science** Þ Use tools to investigate, observe, measure, design, and build things. Þ Recognize and describe ways that some materials, such as recycled paper, cans, and plastic jugs, can be used over again.	Standard 1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that makes these aspects of science meaningful for the student. (see detailed bullet points under 1)Knowledge: Central Concepts, 2)Knowledge: Nature of Science, and 3)Knowledge: Tools of Inquiry). Standard 4: The teacher of science understands and uses a variety of instructional strategies to encourage students' development of conceptual understanding, inquiry skills, and scientific habits of mind. (see detailed Bullet points under Knowledge) *Note: Teachers at this level have in depth preparation in one of the content areas of Appendix C. Alignment has been done using excerpts from the Appendices which apply to all teachers of science and which are referred to in the Comprehensive Standards Document.*
Standard 2. Scientific Thinking **Students begin to find answers to their questions about the world by using measurement, estimations, and observation as well as working with materials. They communicate with others through numbers, words, and drawings.**	**2.1 Computation and Estimation** Þ Give estimates of numerical answers to problems before doing them formally. Þ Make quantitative estimates of familiar lengths, weights, and time intervals and check them by measurements. Þ Estimate and measure capacity using cups and pints. **2.2 Manipulation and Observation** ⇒ Assemble, describe, take apart, and/or reassemble constructions using such things as	Appendix F: Estimation and Computation Skills • including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. • providing experience with basic number skills and computations in meaningful contexts. Appendix F: Manipulation and Observation Skills • providing opportunities to handle common materials and tools for dealing with household and everyday technologies for making careful observations, and for handling information

	interlocking blocks and erector sets. Sometimes pictures or words may be used as a reference. **2.3 Communication Skills** Þ Draw pictures and write brief descriptions that correctly portray key features of an object.	Appendix F: Communication Skills • providing opportunities to communicate ideas and share information with accuracy and clarity and to read and listen with understanding.
<u>**Standard 3. The Physical Setting**</u> **Students investigate, describe, and discuss their natural surroundings. They wonder why things move and change.**	**3.1 The Earth and the Processes that Shape It** Þ Investigate by observing and then describe that some events in nature have a repeating pattern, such as seasons, day and night, and migrations. Þ Investigate, compare, and describe weather changes from day to day but recognize, describe, and chart that the temperature and amounts of rain or snow tend to be high, medium, or low in the same months every year. Þ Investigate by observing and then describing chunks of rocks and their many sizes and shapes, from boulders to grains of sand and even smaller. Þ Investigate by observing and then describing how animals and plants sometimes cause changes in their surroundings. **3.2 Matter and Energy** Þ Investigate that things can be done to materials, such as freezing, mixing, cutting, heating, wetting, etc. to change some of their properties and observe that not all materials respond in the same way. Þ Discuss how people use electricity or burn fuels, such as wood, oil, coal, or natural gas, to cook their food and warm their houses.	Appendix B: Systems Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Constancy, Change and Measurement • Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and matter in systems, and by extension in the universe, remains the same. • Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change

	3.3 Forces of Nature þ Investigate and observe that the way to change how something is moving is to give it a push or a pull. þ Demonstrate and observe that magnets can be used to make some things move without being touched.	
<u>Standard 4. The Living Environment</u> **Students ask questions about a variety of living things and everyday events that can be answered through observations. They consider things and processes that plants and animals need to stay alive. Students begin to understand plant and animal interaction.**	**4.1 Diversity of Life** þ Observe and identify different external features of plants and animals and describe how these features help them live in different environments. **4.2 Interdependence of Life** þ Observe that and describe how animals may use plants, or even other animals, for shelter and nesting. þ Observe and explain that plants and animals both need to take in water, animals need to take in food, and plants need light. þ Recognize and explain that living things are found almost everywhere in the world and that there are somewhat different kinds in different places. þ Recognize and explain that materials in nature, such as grass, twigs, sticks, and leaves, can be recycled and used again, sometimes in different forms, such as in birds' nests. **4.3 Human Identity** þ Observe and describe the different external features of people, such as their size, shape, and color of hair, skin, and eyes. þ Recognize and discuss that people are more like one another than they are like other animals. þ Give examples of different roles people have in families and communities.	Appendix B: System, Order and Organization • Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. • Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions. • Types and levels of organization provide useful ways of thinking about the world. Types of organization include the periodic table of elements and the classification of organisms. Physical systems can be described at different levels of organization--such as fundamental particles, atoms, and molecules. Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions.

<u>Standard 5. The Mathematical World</u> **Students apply mathematics in scientific contexts. They use numbers for computing, estimating, naming, measuring, and communicating specific information. They make picture and bar graphs. They recognize shapes and patterns. They use evidence to explain how or why something happens.**	**5.1 Numbers** Þ Recognize and explain that, in measuring, there is a need to use numbers between whole numbers, such as 2 ½ centimeters. Þ Recognize and explain that it is often useful to estimate qualities. **5.2 Shapes and Symbolic Relationships** Þ Observe that and describe how changing one thing can cause changes in something else, such as exercise and its effect on heart rate. **5.3 Reasoning and Uncertainty** Þ Begin to recognize and explain that people are more likely to believe ideas if good reasons are given for them. Þ Explain that some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms. Understand that people aren't always sure what will happen since they do not know everything that might have an effect. Þ Explain that sometimes a person can find out a lot (but not everything) about a group of things, such as insects, plants, or rocks, by studying just a few of them.	Appendix F: Values and Attitudes in Science ▪ helping people qualitatively and quantitatively and make sense of their natural world. ▪ fostering the attitudes of curiosity, openness to new ideas, and informed skepticism. ▪ developing positive attitudes about science. Appendix B: Forms and Function Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form. The understanding of form and function applies to different levels of organization. Students should be able to explain function by referring to form, and to explain form by referring to function. Appendix B: Constancy, Change and Measurement Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change. Appendix F: Critical-Response Skills ▪ allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. ▪ allowing students to apply those same critical skills to their own observations, arguments, and conclusions.

<u>**Standard 6. Common Themes**</u> **Students begin to observe how objects are similar and how they are different. They begin to identify parts of an object and recognize how these parts interact with the whole. They look for what changes and what does not change and make comparisons.**	**6.1 Systems** Þ Investigate that most objects are made of parts. **6.2 Models and Scales** Þ Observe and explain that models may not be the same size, may be missing some details, or may not be able to do all of the same things as the real things. **6.3 Constancy and Change** Þ Describe that things can change in different ways, such as in size, weight, color, age, and movement. Investigate that some small changes can be detected by taking measurements.	Appendix B: Constancy, Change and Measurement • Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is knowing when to use which system. For example, a meteorologist might use degrees Fahrenheit when reporting the weather to the public, but in writing scientific reports, the meteorologist would use degrees Celsius. • Scale includes understanding that the different characteristics, properties, or relationships within a system might change as its dimensions are increased or decreased. • Although most things are in the process of becoming different--changing--some properties of objects and processes are characterized by constancy, including the speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles. Appendix B: Evidence, Models and Explanation Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

STANDARDS OVERVIEW ACTIVITY: ***What Indiana's students & teachers need to know and be able to do in Science.***

	3rd Grade Student Standard	Teacher Preparation Standard
Standard 1. The Nature of Science and Technology **Students, working collaboratively, carry out investigations. They question, observe, and make accurate measurements. Students increase their use of tools, record data in journals, and communicate results through chart, graph, written, and verbal forms.**	**1.1 The Scientific View of the World** Þ Recognize and explain that when a scientific investigation is repeated, a similar result is expected. **1.2 Scientific Inquiry** Þ Participate in different types of guided scientific investigations, such as observing objects and events and collecting specimens for analysis. Þ Keep and report records of investigations and observations using tools, such as journals, charts, graphs, and computers. Þ Discuss the results of investigations and consider the explanations of others. **1.3 The Scientific Enterprise** Þ Demonstrate the ability to work cooperatively while respecting the ideas of others and communicating one's own conclusions about findings. **1.4 Technology and Science** ⇒ Give examples of how tools, such as automobiles, computers, and electric motors, have affected the way we live. Þ Recognize that and explain how an invention can be used in different ways, such as a radio being used to get information and for entertainment. Þ Describe how discarded products contribute to the problem of waste disposal and that recycling can help solve this problem.	Standard 1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that makes these aspects of science meaningful for the student. (see detailed bullet points under 1)Knowledge: Central Concepts, 2)Knowledge: Nature of Science, and 3)Knowledge: Tools of Inquiry). Standard 4: The teacher of science understands and uses a variety of instructional strategies to encourage students' development of conceptual understanding, inquiry skills, and scientific habits of mind. (see detailed Bullet points under Knowledge) Appendix D: Science and Technology Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. *Note: Teachers at this level have in depth preparation in one of the content areas of Appendix C. Alignment has been done using excerpts from the Appendices which apply to all teachers of science and which are referred to in the Comprehensive Standards Document.*

<u>Standard 2. Scientific Thinking</u> **Students use a variety of skills and techniques when attempting to answer questions and solve problems. They describe their observations accurately and clearly, using numbers, words, and sketches, and are able to communicate their thinking to others.**	**2.1 Computation and Estimation** Þ Add and subtract whole numbers, mentally, on paper, and with a calculator. **2.2 Manipulation and Observation** Þ Measure and mix dry liquid materials in prescribed amounts, following reasonable safety precautions. Þ Keep a notebook that describes observations and is understandable weeks or months later. Þ Appropriately use simple tools, such as clamps, rulers, scissors, hand lenses, and other technology, such as calculators and computers, to help solve problems. Þ Construct something used for performing a task out of paper, cardboard, wood, plastic, metal, or existing objects. **2.3 Communication Skills** Þ Make sketches and write descriptions to aid in explaining procedures or ideas. **2.4 Critical Response Skills** Þ Ask "How do you know?" in appropriate situations and attempt reasonable answers when others ask the same question.	Appendix F: Estimation and Computation Skills • including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. • providing experience with basic number skills and computations in meaningful contexts. Appendix F: Manipulation and Observation Skills • providing opportunities to handle common materials and tools for dealing with household and everyday technologies for making careful observations, and for handling information Appendix F: Communication Skills • providing opportunities to communicate ideas and share information with accuracy and clarity and to read and listen with understanding. Appendix F: Critical-Response Skills ▪ allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. ▪ allowing students to apply those same critical skills to their own observations, arguments, and conclusions.
<u>Standard 3. The Physical Setting</u> **Students observe changes of the Earth and sky. They continue to explore the concepts of energy and motion.**	**3.1 The Universe** Þ Observe and describe the apparent motion of the sun and moon over a time span of one day. Þ Observe and describe that there are more stars in the sky than anyone can easily count, but they are not scattered evenly. Þ Observe and describe that the sun can be seen only in the daytime. Þ Observe and describe that the moon looks a little different every day, but looks the same again about every four weeks.	Appendix B: Systems Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Constancy, Change and Measurement • Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and

	3.2 The Earth and the Processes that Shape It Þ Give examples of how change, such as weather patterns, is a continual process occurring on Earth. Þ Describe ways human beings protect themselves from adverse weather conditions. Þ Identify and explain some effects human activities have on weather. **3.3 Matter and Energy** ⇒ Investigate and describe how moving air and water can be used to run machines, like windmills and waterwheels. **3.4 Forces of Nature** ⇒Demonstrate that things that make sound do so by vibrating, such as vocal cords and musical instruments.	matter in systems, and by extension in the universe, remains the same. • Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change
<u>Standard 4. The Living Environment</u> **Students learn about an increasing variety of organisms. They use appropriate tools and identify similarities and difference among them. Students explore how organisms satisfy their needs in typical environments.**	**4.1 Diversity of Life** Þ Demonstrate that a great variety of living things can be sorted into groups in many ways using various features, such as how they look, where they live, and how they act, to decide which things belong to which group. Þ Explain that features used for grouping depend on the purpose of the grouping. Þ Observe that and describe how offspring are very much, but not exactly, like their parents and like one another. **4.2 Interdependence of Life and Evolution** Þ Describe that almost all kinds of animals'	Appendix B: System, Order and Organization • Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. • Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur.

	food can be traced back to plants. Þ Give examples of some kinds of organisms that have completely disappeared and explain how these organisms were similar to some organisms living today. **4.3 Human Identity** Þ Explain that people need water, food, air, waste removal, and a particular range of temperatures, just as other animals do. Þ Explain that eating a variety of healthful foods and getting enough exercise and rest help people to stay healthy. Þ Explain that some things people take into their bodies from the environment can hurt them and give examples of such things. Þ Explain that some diseases are caused by germs and some are not. Note that diseases caused by germs may be spread to other people. Also understand that washing hands with soap and water reduces the number of germs that can get into the body or that can be passed on to other people.	Further, systems at different levels of organization can manifest different properties and functions. • Types and levels of organization provide useful ways of thinking about the world. Types of organization include the periodic table of elements and the classification of organisms. Physical systems can be described at different levels of organization--such as fundamental particles, atoms, and molecules. Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions PERSONAL AND COMMUNITY HEALTH • Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability, or death may be present. Humans have a variety of mechanisms--sensory, motor, emotional, social, and technological--that can reduce and modify hazards. • The severity of disease symptoms is dependent on many factors, such as human resistance and the virulence of the disease-producing organism. Many diseases can be prevented, controlled, or cured. Some diseases, such as cancer, result form specific body dysfunctions and cannot be transmitted. • Personal choice concerning fitness and health involves multiple factors. Personal goals, peer and social pressures, ethnic and religious beliefs, and understanding of biological consequences can all influence decisions about health practices.

<u>**Standard 5. The Mathematical World**</u> **Students apply mathematics in scientific contexts. Students make more precise and varied measurements when gathering data. Based upon collected data, they pose questions and solve problem. Students use numbers to record data and construct graphs and tables to communicate their findings.**	**5.1 Numbers** Þ Select and use appropriate measuring units, such as centimeters (cm) and meters (m), grams (g) and kilograms (kg), and degrees Celsius (C). Þ Observe that and describe how some measurements are likely to be slightly different, even if what is being measured stays the same. **5.2 Shapes and Symbolic Relationships** Þ Construct tables and graphs to show how values of one quantity are related to values of another. Þ Illustrate that if 0 and 1 are located on a line, any other number can be depicted as a position on the line. **5.3 Reasoning and Uncertainty** Þ Explain that one way to make sense of something is to think of how it relates to something more familiar.	Appendix B: Forms and Function Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form. The understanding of form and function applies to different levels of organization. Students should be able to explain function by referring to form, and to explain form by referring to function. Appendix B: Constancy, Change and Measurement Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change. Appendix B: Evidence, Models, and Explanation Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems.
<u>**Standard 6. Common Themes**</u> **Students work with an increasing variety of systems and begin to modify parts in systems and models and notice changes that result. They question why change occurs.**	**6.1 Systems** Þ Investigate how and describe that when parts are put together, they can do things that they could not do by themselves. Þ Investigate how and describe that something may not work if some of its parts are missing. **6.2 Models and Sale** Þ Explain how a model of something is different from the real thing, but can be used to learn something about the real thing.	Appendix B: Constancy, Change and Measurement • Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is knowing when to use which system. For example, a meteorologist might use degrees Fahrenheit when reporting the weather to the public, but in writing scientific reports, the meteorologist would use degrees Celsius. • Scale includes understanding that the different characteristics, properties, or relationships within a system might change as its dimensions are increased or decreased.

	6.3 Constancy and Change Þ Take, record, and display counts and simple measurements of things over time, such as plant or student growth. Þ Observe that and describe how some changes are very slow and some are very fast and that some of these changes may be hard to see and/or record.	• Although most things are in the process of becoming different--changing--some properties of objects and processes are characterized by constancy, including the speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles. Appendix B: Evidence, Models and Explanation Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

STANDARDS OVERVIEW ACTIVITY: ***What Indiana's students & teachers need to know and be able to do in Science.***

	4th Grade Student Standard	Teacher Preparation Standard
Standard 1. The Nature of Science and Technology **Students, working collaboratively, carry out investigations. They observe and make accurate measurements, increase their use of tools and instruments, record data in journals, and communicate results through chart, graph, written and verbal forms.**	**1.1 The Scientific View of the World** Þ Observe and describe that scientific investigations generally work the same way in different places. **1.2 Scientific Inquiry** Þ recognize and describe that results of scientific investigations are seldom exactly the same. If differences occur, such as a large variation in the measurement of plant growth, propose reasons for why these differences exist, using recorded information about investigations. **1.3 The Scientific Enterprise** Þ Explain that clear communication is an essential part of doing science since it enables scientists to inform others about their work, to expose their ideas to evaluation by other scientists, and to allow scientists to stay informed about scientific discoveries around the world. Þ Describe how people all over the world have taken part in scientific investigation for many centuries. **1.4 Technology and Science** Þ Demonstrate how measuring instruments, such as microscopes, telescopes, and cameras, can be used to gather accurate information for making scientific comparisons of objects and events. Note that measuring instruments, such as rulers, can also be used for designing and constructing things that will work properly. Þ Explain that even a good design may fail even though steps are taken ahead of time to reduce the likelihood of failure. Þ Discuss and give examples of how technology, such as computers and medicines, has improved the lives of many people, although the benefits are not equally available to all. Þ Recognize and explain that any invention may lead to other inventions.	Standard 1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that makes these aspects of science meaningful for the student. (see detailed bullet points under 1)Knowledge: Central Concepts, 2)Knowledge: Nature of Science, and 3)Knowledge: Tools of Inquiry). Standard 4: The teacher of science understands and uses a variety of instructional strategies to encourage students' development of conceptual understanding, inquiry skills, and scientific habits of mind. (see detailed Bullet points under Knowledge). Appendix D: Science and Technology Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. Appendix B: EVIDENCE, MODELS, AND EXPLANATION Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Appendix E: SCIENCE AND TECHNOLOGY IN LOCAL, NATIONAL, AND GLOBAL CHALLENGES Science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen. The latter involves human decisions about the use of knowledge. Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science- and technology-related challenges. However, understanding science alone will not resolve local, national, or global challenges. Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology. *Note: Teachers at this level have in depth preparation in one of the*

	Þ Explain how some products and materials are easier to recycle than others.	*content areas of Appendix C. Alignment has been done using excerpts from the Appendices which apply to all teachers of science and which are referred to in the Comprehensive Standards Document.*
Standard 2. Scientific Thinking **Students use a variety of skills and techniques when attempting to answer questions and solve problems. They describe their observations accurately and clearly, using numbers, words. And sketches, and are able to communicate their thinking to others. They compare, explain, and justify both information and numerical functions.**	**2.1 Computation and Estimation** Þ Judge whether measurements and computations of quantities, such as length, area, volume, weight, or time, are reasonable. Þ State the purpose, orally or in writing, of each step in a computation. **2.2 Manipulation and Observation** Þ Make simple and safe electrical connections with various plugs, sockets, and terminals. **2.3 Communication Skills** Þ Use numerical data to describe and compare objects and events. Þ Write descriptions of investigations, using observations and other evidence as support for explanations. **2.4 Critical Response Skills** Þ Support statements with facts found in print and electronic media, identify the sources used, and expect others to do the same. Þ Identify better reasons for believing something than "Everybody knows that…" or "I just know" and discount such reasons when given by others.	Appendix F: Estimation and Computation Skills • including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. • providing experience with basic number skills and computations in meaningful contexts. Appendix F: Manipulation and Observation Skills • providing opportunities to handle common materials and tools for dealing with household and everyday technologies for making careful observations, and for handling information Appendix F: Communication Skills • providing opportunities to communicate ideas and share information with accuracy and clarity and to read and listen with understanding. Appendix F: Critical-Response Skills ▪ allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. ▪ allowing students to apply those same critical skills to their own observations, arguments, and conclusions.
Standard 3. The Physical Setting	**3.1 The Universe**	Appendix B: Systems Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in

Students continue to investigate changes of the Earth and sky and begin to understand the composition and size of the universe. They explore, describe, and classify materials, motion and energy.	Þ Observe and report that the moon can be seen sometimes at night and sometimes during the day. **3.2 The Earth and the Processes that Shape It** Þ Begin to investigate and explain that air is a substance that surrounds us, takes up space, and whose movements we feel as wind. Þ Identify salt as the major difference between fresh and ocean waters. Þ Describe some of the effects of oceans on climate. Þ Describe how waves, wind, water, and glacial ice shape and reshape the Earth's land surface by the erosion of rock and soil in some areas and depositing them in other areas. Þ Recognize and describe that rock is composed of different combinations of minerals. Þ Explain that smaller rocks come from the breakage and weathering of bedrock and larger rocks and that soil is made partly from weathered rock, partly from plant remains, and also contains many living organisms. Þ Explain that the rotation of the Earth on its axis every 24 hours produces the night-and-day cycle. Þ Draw or correctly select drawings of shadows and their direction and length at different times of day. **3.3 Matter and Energy** Þ Demonstrate that the mass of a whole object is always the same as the sum of the masses of its parts. Þ Investigate, observe, and explain that things that give off light often also give off heat. Þ Investigate, observe, and explain that heat is produced when one object rubs against another, such as one's hands rubbing together. Þ Observe and describe the things that give off	systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Constancy, Change and Measurement • Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and matter in systems, and by extension in the universe, remains the same. • Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change Appendix B:EVOLUTION AND EQUILIBRIUM • Evolution is a series of changes, some gradual and some sporadic, that account for the present form and function of objects, organisms, and natural and designed systems. The general idea of evolution is that the present arises from materials and forms of the past. Although evolution is most commonly associated with the biological theory explaining the process of descent with modification of organisms from common ancestors, evolution also describes changes in the universe. • Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions: for example, opposite forces are of the same magnitude, or off-setting changes occur at equal rates. Steady state, balance, and homeostasis also describe equilibrium states. Interacting units of matter tend toward equilibrium states in which the energy is distributed as randomly and uniformly as possible.

	heat, such as people, animals, and the sun. Þ Explain that energy in fossil fuels comes from plants that grew long ago.	
	3.4 Forces of Nature Þ Demonstrate that without touching them, a magnet pulls all things made of iron and either pushes or pulls other magnets. Þ Investigate and describe that without touching them, material that has been electrically charged pulls all other materials and may either push or pull other charged material.	Appendix B: System, Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world.
<u>Standard 4. The Living Environment</u> **Students learn about an increasing variety of organisms –familiar, exotic, fossil, and microscopic. They use appropriate tools in identifying similarities and differences among them. They explore how organisms satisfy their needs in their environments.**	**4.1 Diversity of Life** Þ Investigate, such as by using microscopes, to see that living things are made mostly of cells. **4.2 Interdependence of Life and Evolution** Þ Investigate, observe, and describe that insects and various other organisms depend on dead plant and animal material for food. Þ Observe and describe that organisms interact with one another in various ways, such as providing food, pollination, and seed dispersal. Þ Observe and describe that some source of energy is needed for all organisms to stay alive and grow. Þ Observe and explain that most plants produce far more seeds than those that actually grow into new plants. Þ Explain how in all environments, organisms are growing, dying, decaying, and new organisms are being produced by the old ones. **4.3 Human Identity** Þ Describe that human beings have made tools and machines, such as x-rays, microscopes, and computers, to sense and do things that they could not otherwise sense or do at all, or as quickly, or as well. Þ Know and explain that artifacts and preserved	Appendix B: Systems, Order and Organization Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions. Appendix D: Science and Technology • IDENTIFY A PROBLEM OR DESIGN AN OPPORTUNITY: Students should be able to identify new problems or needs and to change and improve current technological designs. • PROPOSE DESIGNS AND CHOOSE BETWEEN ALTERNATIVE SOLUTIONS: Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes. • IMPLEMENT A PROPOSED SOLUTION: A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials--such as wood,

	remains provide some evidence of the physical characteristics and possible behavior of human beings who lived a very long time ago. Þ Explain that food provides energy and materials for growth and repair of body parts. Recognize that vitamins and minerals, present in small amounts in foods, are essential to keep everything working well. Further understand that as people grow up, the amounts and kinds of food and exercise needed by the body may change. Þ Explain that if germs are able to get inside the body, they may keep it from working properly. Understand that for defense against germs, the human body has tears, saliva, skin, some blood cells, and stomach secretions. Also note that a healthy body can fight most germs that invade it. Recognize, however, that there are some germs that interfere with the body's defenses. Þ Explain that there are some diseases that human beings can only catch once. Explain that there are many diseases that can be prevented by vaccinations, so that people do not catch them even once.	metal, plastics, and textiles. Solutions can also be implemented using computer software. Appendix E: Science in Personal and Social Perspectives: PERSONAL AND COMMUNITY HEALTH ▪ Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability, or death may be present. Humans have a variety of mechanisms--sensory, motor, emotional, social, and technological--that can reduce and modify hazards. ▪ The severity of disease symptoms is dependent on many factors, such as human resistance and the virulence of the disease-producing organism. Many diseases can be prevented, controlled, or cured. Some diseases, such as cancer, result form specific body dysfunctions and cannot be transmitted. Appendix E: Science in Personal and Social Perspectives <u>PERSONAL AND COMMUNITY HEALTH</u> ▪ Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability, or death may be present. Humans have a variety of mechanisms--sensory, motor, emotional, social, and technological--that can reduce and modify hazards. ▪ The severity of disease symptoms is dependent on many factors, such as human resistance and the virulence of the disease-producing organism. Many diseases can be prevented, controlled, or cured. Some diseases, such as cancer, result form specific body dysfunctions and cannot be transmitted.

Standard 5. The Mathematical World **Students apply mathematics in scientific contexts. Their geometric descriptions of objects are comprehensive. They realize that graphing demonstrates specific connections between the data. They identify questions that can be answered by data distribution.**	**5.1 Numbers** Þ Explain that the meaning of numerals in many-digit numbers depends on their positions. Þ Explain that in some situations, “0” means none of something, but in others, it may be just the label of some point on a scale. **5.2 Shapes and Symbolic Relationships** Þ Illustrate how length can be thought of as unit lengths joined together, area as a collection of unit squares, and volume as a set of unit cubes. Þ Demonstrate how graphical displays of numbers may make it possible to spot patterns that are not otherwise obvious, such as comparative size and trends. **5.3 Reasoning and Uncertainty** Þ Explain how reasoning can be distorted by strong feelings.	Appendix B: Forms and Function Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form. The understanding of form and function applies to different levels of organization. Students should be able to explain function by referring to form, and to explain form by referring to function. Appendix B: Constancy, Change and Measurement Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change. Appendix B: Evidence, Models, and Explanation Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Appendix F: Critical-Response Skills • allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. • allowing students to apply those same critical skills to their own observations, arguments, and conclusions
Standard 6. Common Themes **Students work with an increasing variety of systems and begin to modify parts in systems and models and notice the changes that result. They question why change occurs.**	**6.1 Systems** Þ Demonstrate that in an object consisting of many parts, the parts usually influence or interact with one another. Þ Show how something may not work as well, or at all, if a part of it is missing, broken, worn out, mismatched, or incorrectly connected.	Appendix B: Constancy, Change and Measurement • Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is knowing when to use which system. For example, a meteorologist might use degrees Fahrenheit when reporting the weather to the public, but in writing scientific reports, the meteorologist would use degrees Celsius. • Scale includes understanding that the different characteristics, properties, or relationships within a system

	6.2 Models and Scale Þ Recognize that and describe how changes made to a model can help predict how the real thing can be altered. **6.3 Constancy and Change** Þ Observe and describe that some features of things may stay the same even when other features change.	might change as its dimensions are increased or decreased. • Although most things are in the process of becoming different--changing--some properties of objects and processes are characterized by constancy, including the speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles. Appendix B: Evidence, Models and Explanation Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

STANDARDS OVERVIEW ACTIVITY: ***What Indiana's students & teachers need to know and be able to do in Science.***

	5th Grade Student Standard	**Teacher Preparation Standard**
Standard 1. The Nature of Science Technology **Students work collaboratively to carry out investigations. They observe and make accurate measurements, increase their use of tools and instruments, record date in journals, and communicate results through charts, graphs, written, and verbal forms. Students repeat investigations, explain inconsistencies, and design projects.**	**1.1 The Scientific View of the World** Þ Recognize and describe that results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations. **1.2 Scientific Inquiry** Þ Begin to evaluate the validity of claims based on the amount and quality of the evidence cited. **1.3 The Scientific Enterprise** Þ Explain that doing science involves many different kinds of work and engages men, women, and children of all ages and backgrounds. **1.4 Technology and Science** Þ Give examples of technology, such as telescopes, microscopes, and cameras, that enable scientists and others to observe things that are too small or too far away to be seen without them and to study the motion of objects that are moving very rapidly or are hardly moving. Þ Explain that technology extends the ability of people to make positive and/or negative changes in the world. Þ Explain how the solution to one problem, such as the use of pesticides in agriculture or the use of dumps for waste disposal, may create other problems. Þ Give examples of materials not present in nature, such as cloth, plastic, and concrete, that have become available because of science and technology.	Standard 1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that makes these aspects of science meaningful for the student. (see detailed bullet points under 1)Knowledge: Central Concepts, 2)Knowledge: Nature of Science, and 3)Knowledge: Tools of Inquiry). Standard 4: The teacher of science understands and uses a variety of instructional strategies to encourage students' development of conceptual understanding, inquiry skills, and scientific habits of mind. (see detailed Bullet points under Knowledge). Appendix D: Science and Technology Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. Appendix B: EVIDENCE, MODELS, AND EXPLANATION Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. *Note: Teachers at this level have in depth preparation in one of the content areas of Appendix C. Alignment has been done using excerpts from the Appendices which apply to all teachers of science and which are referred to in the Comprehensive Standards Document.*

<u>Standard 2. Scientific Thinking</u> **Students use a variety of skills and techniques when attempting to answer questions and solve problems. Students describe their observations accurately and clearly using numbers, words, sketches, and are able to communicate their thinking to others. They compare. Contrast, explain, and justify both information and numerical functions.**	**2.1 Computation and Estimation** Þ Multiply and divide whole numbers mentally, on paper, and with a calculator. Þ Use appropriate fractions and decimals when solving problems. **2.2 Manipulation and Observation** Þ Choose appropriate common materials for making simple mechanical constructions and repairing things. Þ Keep a notebook to record observations and be able to distinguish inferences from actual observations. Þ Use technology, such as calculators or spreadsheets, in determining area and volume from linear dimensions. Find area, volume, mass, time, and cost, and find the difference between two quantities of anything. **2.3 Communication Skills** Þ Write instructions that others can follow in carrying out a procedure. Þ Read and follow step-by-step instructions when learning new procedures. **2.4 Critical Response Skills** Þ Recognize when and describe that comparisons might not be accurate because some of the conditions are not kept the same.	Appendix F: Estimation and Computation Skills • including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. • providing experience with basic number skills and computations in meaningful contexts. Appendix F: Manipulation and Observation Skills • providing opportunities to handle common materials and tools for dealing with household and everyday technologies for making careful observations, and for handling information Appendix F: Communication Skills • providing opportunities to communicate ideas and share information with accuracy and clarity and to read and listen with understanding. Appendix F: Critical-Response Skills ▪ allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. ▪ allowing students to apply those same critical skills to their own observations, arguments, and conclusions.
<u>Standard 3. The Physical Setting</u> **Students continue to investigate changes of the Earth and sky. They explore, describe, and classify materials, motion, and energy.**	**3.1 The Universe** Þ Explain that telescopes are used to magnify distant objects in the sky including the moon and the planets. Þ Observe and describe that stars are like the sun, some being smaller and some being larger, but they are so far away that they look like points of light.	Appendix B: Systems, Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Constancy, Change and Measurement • Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and matter in systems, and by extension in the universe, remains the same.

	Þ Observe the stars and identify stars that are unusually bright and those that have unusual colors, such as reddish or bluish. **3.2 The Earth and the Processes that Shape It** Þ Investigate that when liquid water disappears it turns into a gas (vapor) mixed into the air and can reappear as a liquid when cooled or as a solid if cooled below the freezing point of water. Þ Observe and explain that clouds and fog are made of tiny droplets of water. Þ Demonstrate that things on or near the Earth are pulled toward it by the Earth's gravity. Þ Describe that, like all planets and stars, the Earth is approximately spherical in shape. **3.3 Matter and Energy** Þ Investigate, observe, and describe that heating and cooling cause changes in the properties of materials, such as water turning into steam by boiling and water turning into ice by freezing. Notice that many kinds of changes occur faster at higher temperatures. Þ Investigate, observe, and describe that when warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are all at the same temperature. Demonstrate that a warmer object can warm a cooler one by contact or at a distance. Þ Investigate that some materials conduct heat much better than others, and poor conductors can reduce heat loss. **3.4 Forces of Nature** ⇒ Investigate and describe that changes in speed or direction of motion of an object are caused by forces. Understand that the greater the force, the greater the change in motion and the more massive an object, the less effect a given force will have. Þ Explain that objects move at different rates, with some moving very slowly and some	• Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change Appendix B:EVOLUTION AND EQUILIBRIUM • Evolution is a series of changes, some gradual and some sporadic, that account for the present form and function of objects, organisms, and natural and designed systems. The general idea of evolution is that the present arises from materials and forms of the past. Although evolution is most commonly associated with the biological theory explaining the process of descent with modification of organisms from common ancestors, evolution also describes changes in the universe. • Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions: for example, opposite forces are of the same magnitude, or off-setting changes occur at equal rates. Steady state, balance, and homeostasis also describe equilibrium states. Interacting units of matter tend toward equilibrium states in which the energy is distributed as randomly and uniformly as possible.

<u>Standard 4. The Living Environment</u> **Students learn about an increasing variety of organisms – familiar, exotic, fossil, microscopic. They use appropriate tools in identifying similarities and differences among these organisms. Students explore how organisms satisfy their needs in their environments.**	moving too quickly for people to see them. Þ Demonstrate that the Earth's gravity pulls any object toward it without touching it. **4.1 Diversity of Life** Þ Explain that for offspring to resemble their parents there must be a reliable way to transfer information from one generation to the next. Þ Observe and describe that some living things consist of a single cell that needs food, water, air, a way to dispose of waste, and an environment in which to live. Þ Observe and explain that some organisms are made of a collection of similar cells that benefit from cooperating. Explain that some organisms' cells, such as human nerve cells and muscle cells, vary greatly in appearance and perform very different roles in the organism. **4.2 Interdependence of Life and Evolution** Þ Explain that in any particular environment, some kinds of plants and animals survive well, some do not survive as well, and some cannot survive at all. Þ Explain that changes in an organism's habitat are sometimes beneficial and sometimes harmful. Þ Recognize and explain that most microorganisms do not cause disease and many are beneficial. Þ Explain that living things, such as plants and animals, differ in their characteristics, and that sometimes these differences an give members of these groups (plants and animals) an advantage in surviving and reproducing. **4.3 Human Identity** Þ Explain that like other animals, human beings have body systems.	Appendix B: System, Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Systems, Order and Organization Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions. Appendix D: Science and Technology • IDENTIFY A PROBLEM OR DESIGN AN OPPORTUNITY: Students should be able to identify new problems or needs and to change and improve current technological designs. • PROPOSE DESIGNS AND CHOOSE BETWEEN ALTERNATIVE SOLUTIONS: Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes. • IMPLEMENT A PROPOSED SOLUTION: A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials--such as wood, metal, plastics, and textiles. Solutions can also be implemented using computer software.

<u>**Standard 5. The Mathematical World**</u> **Students apply mathematics in scientific contexts. They make more precise and varied measurements in gathering data. Their geometric descriptions of objects are comprehensive, and their graphing demonstrates specific connections. They identify questions that can be answered by data distribution, i.e. "Where is the middle?" and their supporting of claims or answers with reasons and analogies becomes important.**	**5.1 Numbers** Þ Make precise and varied measurements and specify the appropriate units. **5.2 Shapes and Symbolic Relationships** Þ Show that mathematical statements using symbols may be true only when the symbols are replaced by certain numbers. Þ Classify objects in terms of simple figures and solids. Þ Compare shapes in terms of concepts, such as parallel and perpendicular, congruence and symmetry. Þ Demonstrate that areas of irregular shapes can be found by dividing them into squares and triangles. Þ Describe and use drawings to show shapes and compare locations of things very different in size. **5.3 Reasoning and Uncertainty** Þ Explain that predictions can be used on what is known about the past, assuming that conditions are similar. Þ Realize and explain that predictions may be more accurate if they are based on large collections of objects or events. Þ Show how spreading data out on a number line helps to see what the extremes are, where they pile up, and where the gaps are. Þ Explain the danger in using only a portion of the data collected to describe the whole.	Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form. The understanding of form and function applies to different levels of organization. Students should be able to explain function by referring to form, and to explain form by referring to function. Appendix B: Constancy, Change and Measurement Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change. Appendix B: Evidence, Models, and Explanation Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Appendix F: Critical-Response Skills • allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. • allowing students to apply those same critical skills to their own observations, arguments, and conclusions Appendix F: Estimation and Computation Skills ▪ including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. ▪ providing experience with basic number skills and computations in meaningful contexts.

<u>Standard 6. Common Themes</u> **Students work with an increasing variety of systems and begin to modify parts in systems and models and notice changes that result.**	**6.1 Systems** Þ Recognize and describe that systems contain objects as well as processes that interact with each other. **6.2 Models and Scales** Þ Demonstrate how geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representation can never be exact in every detail. Þ Recognize and describe that almost anything has limits on how big or small it can be. **6.3 Constancy and Change** Þ Investigate, observe, and describe that things change in steady, repetitive, or irregular ways, such as toy cars continuing in the same direction and air temperature reading a high or low value. Note that the best way to tell which kinds of change are happening is to make a table or graph of measurements.	Appendix B: Constancy, Change and Measurement • Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is knowing when to use which system. For example, a meteorologist might use degrees Fahrenheit when reporting the weather to the public, but in writing scientific reports, the meteorologist would use degrees Celsius. • Scale includes understanding that the different characteristics, properties, or relationships within a system might change as its dimensions are increased or decreased. • Although most things are in the process of becoming different--changing--some properties of objects and processes are characterized by constancy, including the speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles. Appendix B: Evidence, Models and Explanation Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

STANDARDS OVERVIEW ACTIVITY: ***What Indiana's students and teachers need to know and be able to do in Science.***

	6th Grade Student Standard	Teacher Preparation Standard
Standard 1. The Nature of Science and Technology **Students design investigations. They use computers and other technologies to collect and analyze data; they explain findings, and can relate how they conduct investigations to how the scientific enterprise functions as a whole. Students understand that technology has allowed humans to do many things, yet it cannot always provide solutions to our needs.**	**1.1 The Scientific View of the World** Þ Explain that some scientific knowledge, such as the length of the year, is very old and yet is still applicable today. Understand, however, that scientific knowledge is never exempt from review and criticism. **1.2 Scientific Inquiry** Þ Give examples of different ways scientists investigate natural phenomena and identify processes all scientists use, such as collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations, in order to make sense of the evidence. Þ Recognize and explain that hypotheses are valuable, even if they turn out not to be true, if they lead to fruitful investigations. **1.3 The Scientific Enterprise** Þ Give examples of employers who hire scientists, such as colleges and universities, businesses and industries, hospitals, and many government agencies. Þ Identify places where scientists work, including offices, classrooms, laboratories, farms, factories, and natural field settings ranging from space to the ocean floor. Þ Explain that computers have become invaluable in science because they speed up and extend people's ability to collect, store, compile, and analyze data, prepare research reports, and share date and ideas with investigators all over the world. **1.4 Technology and Science** Þ Explain that technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, data collection and storage, computation, and communication information. Þ Describe instances showing that technology cannot always provide successful solutions for	Standard 1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that makes these aspects of science meaningful for the student. (see detailed bullet points under 1)Knowledge: Central Concepts, 2)Knowledge: Nature of Science, and 3)Knowledge: Tools of Inquiry). Standard 4: The teacher of science understands and uses a variety of instructional strategies to encourage students' development of conceptual understanding, inquiry skills, and scientific habits of mind. (see detailed Bullet points under Knowledge). Appendix D: Science and Technology Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. Appendix B: EVIDENCE, MODELS, AND EXPLANATION Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Appendix E: SCIENCE AND TECHNOLOGY IN LOCAL, NATIONAL, AND GLOBAL CHALLENGES Science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen. Progress in science and technology can be affected by social issues and challenges. *Note: Teachers at this level have in depth preparation in one of the content areas of Appendix C. Alignment has been done using excerpts from the Appendices which apply to all teachers of science and which are referred to in the Comprehensive Standards Document.*

	problems or fulfill every human need. Þ Explain how technologies can influence all living things.	
<u>Standard 2. Scientific Thinking</u> **Students use computers and other tools to collect information, calculate, and analyze data. They prepare tables and graphs, using these to summarize data and identify relationships.**	**2.1 Computation and Estimation** ⇨ Find the mean and median of a set of data. ⇨ Use technology, such as calculators or computer spreadsheets, in analysis of data. **2.2 Manipulation and Observation** ⇨ Select tools, such as cameras and tape recorders, for capturing information. ⇨Inspect, dissemble, and reassemble simple mechanical devices and describe what the various parts are for. Estimate what the effect of making a change in one part of a system is likely to have on the system as a whole. **2.3 Communication Skills** ⇨ Organize information in simple tables and graphs and identify relationships they reveal. Use tables and graphs for examples of evidence for explanations when writing essays or writing about lab work, fieldwork, etc. ⇨ Read simple tables and graphs produced by others and describe in words what they show. ⇨Locate information in reference books, back issues of newspapers and magazines, compact disks, and computer databases. ⇨ Analyze and interpret a given set of findings, demonstrating that there may by more than one good way to do so. **2.4 Critical Response Skills** ⇨Compare consumer products, such as generic and brand-name products, and consider reasonable personal trade-offs among them on the basis of features, performance, durability, and costs.	Appendix F: Estimation and Computation Skills • including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. • providing experience with basic number skills and computations in meaningful contexts. Appendix F: Manipulation and Observation Skills • providing opportunities to handle common materials and tools for dealing with household and everyday technologies for making careful observations, and for handling information Appendix F: Communication Skills • providing opportunities to communicate ideas and share information with accuracy and clarity and to read and listen with understanding. Appendix F: Critical-Response Skills ▪ allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. ▪ allowing students to apply those same critical skills to their own observations, arguments, and conclusions.

<u>Standard 3. The Physical Setting</u> **Students collect and organize data to identify relationships between physical objects, events, and processes. They use logical reasoning to question their own ideas as new information challenges their conceptions of the natural world.**	**3.1 The Universe** ⇨ Compare and contrast the size, composition, and surface features of the planets that comprise the solar system, as well as the objects orbiting them. Explain that the planets, except Pluto, move around the sun in nearly circular orbits. ⇨Observe and describe that planets change their position relative to the background of stars. ⇨Explain that the Earth is one of several planets that orbit the sun, and that the moon, as well as many artificial satellites and debris, orbit around the Earth. **3.2 The Earth and the Processes that Shape It** ⇨ Explain that we live on a planet which appears at present to be the only body in the solar system capable of supporting life. ⇨ Use models or drawings to explain that the Earth has different seasons and weather patterns because it turns daily on an axis that is tilted relative to the plane of the Earth's yearly orbit around the sun. Know that because of this, sunlight falls more intensely on different parts of the Earth during the year (the accompanying greater length of days also has an effect) and the difference in heating produces seasons and weather patterns. ⇨Use models or drawings to explain that the phases of the moon are caused by the moon's orbit around the Earth, once in about 28 days, changing what part of the moon is lighted by the sun and how much of that part can be seen from the Earth, both during the day and night. ⇨Understand and describe the scales involved in characterizing the Earth and its atmosphere. Describe that the Earth is mostly rock, that three-fourths of its surface is covered by a relatively thin layer of water, and that the entire planet is surrounded by a relatively thin blanket of air. ⇨Explain that fresh water, limited in supply and uneven in distribution, is essential for life and also for most industrial processes. Understand that this resource can be depleted or polluted, making it	Appendix B: Systems Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Constancy, Change and Measurement • Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and matter in systems, and by extension in the universe, remains the same. • Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change <u>Appendix B:EVOLUTION AND EQUILIBRIUM</u> • Evolution is a series of changes, some gradual and some sporadic, that account for the present form and function of objects, organisms, and natural and designed systems. The general idea of evolution is that the present arises from materials and forms of the past. Although evolution is most commonly associated with the biological theory explaining the process of descent with modification of organisms from common ancestors, evolution also describes changes in the universe. • Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions: for example, opposite forces are of the same magnitude, or off-setting changes occur at equal rates. Steady state, balance, and homeostasis also describe equilibrium states. Interacting units of matter tend toward equilibrium states in which the energy is distributed as randomly and uniformly as possible.

	unavailable or unsuitable for life. ⇨Illustrate that the cycling of water in and out of the atmosphere plays an important role in determining climatic patterns. ⇨Describe the motions of ocean waters, such as tides, and identify their causes. ⇨Identify and explain the effects of oceans on climate. ⇨Describe ways human beings protect themselves from adverse weather conditions. ⇨Identify, explain, and discuss some effects human activities, such as the creation of pollution, have one weather and the atmosphere. ⇨Give examples of some minerals that are very rare and some that exist in great quantities. Explain how recycling and the development of substitutes can reduce that rate of depletion of minerals. ⇨Explain that although weathered rock is the basic component of soil, the composition and texture of soil and its fertility and resistance to erosion are greatly influenced by plant roots and debris, bacteria, fungi, worms, insects, and other organisms. ⇨Explain that human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and farming intensively, have changed the capacity of the environment to support some life forms. **3.3 Matter and Energy** ⇨Recognize and describe that energy is a property of many objects and is associated with heat, light, electricity, mechanical motion, and sound. ⇨Investigate and describe that when a new material, such as concrete, is made by combining two or more materials, it has properties that are different from the original materials. ⇨ Investigate that materials may be composed of parts that are too small to be seen without magnification. ⇨Investigate that equal volumes of different	

	substances usually have different masses as well as different densities. **3.4 Forces of Nature** ⇨Investigate, using a prism for example, that light is made up of a mixture of many different colors of light, even though the light is perceived as almost white. ⇨Demonstrate that vibrations in materials set up wavelike disturbances that spread away fron the source, such as sound and earthquake waves ⇨ Explain that electrical circuits provide a means of transferring electrical energy from sources such as generators to devices in which heat, light, sound, and chemical changes are produced.	Appendix B: System, Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world.
<u>Standard 4. The Living Environment</u> **Students recognize that plants and animals obtain energy in different ways, and they can describe some of the internal structures of organisms related to this function. They examine the similarities and differences between humans and other species. They use microscopes to observe cells and recognize cells as the building blocks of all life.**	**4.1 Diversity of Life** ⇨Explain that one of the most general distinctions among organisms is between green plants, which use sunlight to make their own food, and animals, which consume energy-rich foods. ⇨Give examples of organisms that cannot be neatly classified as either plants or animals, such as fungi and bacteria. ⇨Describe some of the great variety of body plans and internal structures animals and plants have that contribute to their being able to make or find food and reproduce. ⇨Recognize and describe that a species comprises all organisms that can mate with one another to produce fertile offspring. ⇨Investigate and explain that all living things are composed of cells whose details are usually visible only through a microscope. ⇨Distinguish the main differences between plant and animal cells, such as the presence of chlorophyll and cell walls in plant cells and their absence in animal cells. ⇨Explain that about two thirds of the mass of a cell is accounted for by water. Understand that water gives cells many of their properties.	Appendix B: Systems, Order and Organization Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions. Appendix D: Science and Technology • IDENTIFY A PROBLEM OR DESIGN AN OPPORTUNITY: Students should be able to identify new problems or needs and to change and improve current technological designs. • PROPOSE DESIGNS AND CHOOSE BETWEEN ALTERNATIVE SOLUTIONS: Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes. • IMPLEMENT A PROPOSED SOLUTION: A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials--such as wood,

	4.2 Interdependence of Life and Evolution ⇨ Explain that in all environments, such as freshwater, marine, forest, desert, grassland, mountain, and others, organisms with similar needs may compete with one another for resources, including food, space, water, air, and shelter. Note that in any environment, the growth and survival of organisms depend on the physical conditions. ⇨ Recognize and explain that two types of organisms may interact in a competitive or cooperative relationship, such as producer, consumer, predator/prey, or parasite/ host. ⇨ Describe how life on Earth depends on energy from the sun. **4.3 Human Identity** ⇨Describe that human beings have body systems for obtaining and providing energy, defense, reproduction, and the coordination of body functions. ⇨ Explain that human beings have many similarities and differences and that the similarities make it possible for human beings to reproduce and to donate blood and organs to one another. ⇨ Given examples of how human beings use technology to match or exceed many of the abilities of other species.	metal, plastics, and textiles. Solutions can also be implemented using computer software. Appendix E: Science and Technology in Local, National, and Global Challenges • Humans have a major effect on other species. For example, the influence of humans on other organisms occurs through land use--which decreases space available to other species--and pollution--which changes the chemical composition of air, soil, and water.
<u>Standard 5. The Mathematical World</u> **Students apply mathematics in scientific contexts. They use mathematical ideas, such as relations between operations, symbols, shapes in three dimensions, statistical relationships, and the use of logical reasoning, to represent and synthesize data.**	**5.1 Numbers** ⇨Demonstrate that the operations addition and subtraction are inverses and that multiplication and division are inverses of each other. ⇨ Evaluate the precision and usefulness of data based on measurements taken. **5.2 Shapes and Symbolic Relationships** ⇨Explain why shapes on a sphere like the Earth cannot be depicted on a flat surface without some distortion.	Appendix B: Constancy, Change and Measurement Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change.

	⇨Demonstrate how graphs may help to show patterns, such as trends, varying rates of changes, gaps, or clusters, which can be used to make predictions. **5.3 Reasoning and Uncertainty** ⇨Explain the strengths and weaknesses of using an analogy to help describe an event, object, etc. ⇨Predict the frequency of the occurrence of future events based on data. ⇨ Demonstrate how probabilities and ratios can be expressed as fractions, percentages, or odds.	Appendix B: Evidence, Models, and Explanation • Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. • Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations. • Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Appendix F: Critical-Response Skills • allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. • allowing students to apply those same critical skills to their own observations, arguments, and conclusions
Standard 6. Historical Perspectives **Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, that the ideas are often rejected by the scientific establishment, that the ideas sometimes spring from unexpected findings, and that the ideas grow or transform slowly through the contributions of many different investigators.**	**6.1 Historical Perspectives** ⇨ Understand and explain that from the earliest times until now, people have believed that even though countless different kinds of materials seem to exist in the world, most things can be made up of combinations of just a few basic kinds of things. Note that there has not always been agreement, however on what those basic kinds of things are,	Appendix F: Estimation and Computation Skills ▪ including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. ▪ providing experience with basic number skills and computations in meaningful contexts. Standard #1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in

<u>Standard 7. Common Themes</u> **Students use mental and physical models to conceptualize processes. They recognize that many systems have feedback mechanisms that limit changes.**	such as the theory of long ago that the basic substances were earth, water, air, and fire. Understand that this theory seemed to explain many observations about the world, but as we know now, it fails to explain many others. ⇨ Understand and describe that scientists are still working out the details of what the basic kinds of matter are on the smallest scale, and of how they combine, or can be made to combine, to make other substances. ⇨ Understand and explain that they experimental and theoretical work done by French scientist Antoine Lavoisier in the decade between the American and French Revolutions contributed crucially to the modern science of chemistry. **7.1 Systems** ⇨ Describe that a system, such as the human body, is composed of subsystems. **7.2 Models and Scales** ⇨ Use models to illustrate processes that happen too slowly, too quickly, or on too small a scale to observe directly, or are too vast to be changed deliberately, or are potentially dangerous. **7.3 Constancy and Change** ⇨Identify examples of feedback mechanisms within systems that serve to keep changes within specified limits.	order to create learning experiences that make these aspects of science meaningful for the student. (See bullets under *History of Science:* • The teacher of science knows that the history of science can help students build an understanding of the scientific enterprise. • The teacher of science recognizes that some episodes in the history of science have led to major changes in our view of the world. • The teacher of science knows that science often changes by small modifications in existing knowledge, but that new scientific ideas that lead to major changes in scientific thinking can be slow to be accepted. • The teacher of science knows that science has been practiced by different individuals in different cultures throughout history. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles) Appendix B: Constancy, Change and Measurement • Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is knowing when to use which system. • Scale includes understanding that the different characteristics, properties, or relationships within a system might change as its dimensions are increased or decreased. • Although most things are in the process of becoming different--changing--some properties of objects and processes are characterized by constancy, including the

		speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles. Appendix B: Evidence, Models and Explanation Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

STANDARDS OVERVIEW ACTIVITY: ***What Indiana's students & teachers need to be able to do and learn in Science.***

	7th Grade Student Standard	**Teacher Preparation Standard**
Standard 1. The Nature of Science and Technology **Students further their scientific understanding of the natural world through investigations, experiences, and readings. They design solutions to practical problems by using a variety of scientific methodologies.**	**1.1 The Scientific View of the World** ⇨ Recognize and explain that when similar investigations give different results, the scientific challenge is to judge whether the differences are trivial or significant, which often takes further studies to decide. **1.2 Scientific Inquiry** ⇨ Explain that what people expect to observe often affects what they actually do observe and provide an example of a solution to this problem. ⇨ Explain why it is important in science to keep honest, clear, and accurate records. ⇨ Describe that different explanations can be given for the same evidence, and it is not always possible to tell which one is correct without further inquiry. **1.3 The Scientific Enterprise** ⇨ Identify some important contributions to the advancement of science, mathematics, and technology that have been made by different kinds of people, in different cultures, at different times. ⇨ Provide examples of people who overcame bias and/or limited opportunities in education and employment to excel in the fields of science. **1.4 Technology and Science** ⇨ Explain how engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems. ⇨ Explain that technologies often have drawbacks as well as benefits. Consider a technology, such as the use of pesticides, which helps some organisms but may hurt others, either deliberately or inadvertently. ⇨ Explain how societies influence what types of technology are developed and used in such fields as agriculture, manufacturing, sanitation, medicine, warfare, transportation, information processing and communication.	Standard 1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that makes these aspects of science meaningful for the student. (see detailed bullet points under 1)Knowledge: Central Concepts, 2)Knowledge: Nature of Science, and 3)Knowledge: Tools of Inquiry). Standard 4: The teacher of science understands and uses a variety of instructional strategies to encourage students' development of conceptual understanding, inquiry skills, and scientific habits of mind. (see detailed Bullet points under Knowledge). Appendix D: Science and Technology Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. Appendix B: EVIDENCE, MODELS, AND EXPLANATION Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Appendix E: SCIENCE AND TECHNOLOGY IN LOCAL, NATIONAL, AND GLOBAL CHALLENGES Science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen. Progress in science and technology can be affected by social issues and challenges. *Note: Teachers at this level have in depth preparation in one of the content areas of Appendix C. Alignment has been done using the Appendices which apply to all teachers of science.*

	⇨ Identify ways that technology has strongly influences the course of history and continues to do so. ⇨ Illustrate how numbers can be represented by using sequences of only two symbols, such as 1 and 0 or on and off, and how that affects the storage of information in our society.	
<u>**Standard 2. Scientific Thinking**</u> **Students use instruments and tools to measure, calculate, and organize data. They frame arguments in quantitative terms when possible. They question claims and understand that findings may be interpreted in more than one acceptable way.**	**2.1 Computation and Estimation** ⇨Find what percentage one number is of another and figure any percentage of any number. ⇨ Use formulas to calculate the circumferences and areas of rectangles, triangles, and circles, and the volumes of rectangular solids. ⇨Decide what degree of precision is adequate, based on the degree of precision of the original date, and round off the result of calculator operations to significant figures that reasonably reflect those of the inputs. ⇨Express numbers like 100, 1,000, and 1,000,000 as powers of 10. ⇨Estimate probabilities of outcomes in familiar situations, on the basis of history or the number of possible outcomes. **2.2 Manipulation and Observation** ⇨ Read analog and digital meters on instruments used to make direct measurements of length, volume, weight, elapsed time, rates, or temperatures, and choose appropriate units. **2.3 Communication Skills** ⇨ Incorporate circle charts, bar and line graphs, diagrams, scatter plots, and symbols into writing, such as lab or research reports, to serve as evidence for claims and/or conclusions. **2.4 Critical Response Skills** ⇨ Question claims based on vague attributes such as "Leading doctors say…" or on statements made by celebrities or others outside	Appendix F: Estimation and Computation Skills • including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. • providing experience with basic number skills and computations in meaningful contexts. Appendix F: Manipulation and Observation Skills • providing opportunities to handle common materials and tools for dealing with household and everyday technologies for making careful observations, and for handling information Appendix F: Communication Skills • providing opportunities to communicate ideas and share information with accuracy and clarity and to read and listen with understanding. Appendix F: Critical-Response Skills ▪ allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. ▪ allowing students to apply those same critical skills to their own observations, arguments, and conclusions.

<u>Standard 3. The Physical Setting</u> **Students collect and organize data to identify relationships between physical objects, events, and processes. They use logical reasoning to question their own ideas as new information challenges their conception of the natural world.**	the area of their particular expertise. **3.1 The Universe** ⇨ Recognize and describe that the sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars and that the universe contains many billions of galaxies and each galaxy contains many billions of stars. ⇨ Recognize and describe that the sun is many thousands of times closer to the Earth than any other star, allowing light from the sun to reach the Earth in a few minutes. Note that this may be compared to time spans of longer than a year for all other stars. **3.2 The Earth and The Processes that Shape It** ⇨ Describe how climates sometimes have changed abruptly in the past as a result of changes in the Earth's crust, such as volcanic eruptions or impacts of huge rocks from space. ⇨ Explain how heat flow and movement of material within the Earth causes earthquakes and volcanic eruptions and creates mountains and ocean basins. ⇨ Recognize and explain that heat energy carried by ocean currents has a strong influence on climate around the world. ⇨ Describe how gas and dust from large volcanoes can change the atmosphere. ⇨ Give examples of some changes in the Earth's surface that are abrupt, such as earthquakes and volcanic eruptions, and some changes that happen very slowly, such as uplift and wearing down of mountains, and the action of glaciers. ⇨ Describe how sediments of sand and smaller particles, sometimes containing the remains of organisms, are gradually buried and are cemented together by dissolved minerals to form solid rock again. ⇨ Explain that sedimentary rock, when buried deep enough, may be reformed by pressure and	Appendix B: Systems Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Constancy, Change and Measurement • Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and matter in systems, and by extension in the universe, remains the same. • Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change <u>Appendix B:EVOLUTION AND EQUILIBRIUM</u> • Evolution is a series of changes, some gradual and some sporadic, that account for the present form and function of objects, organisms, and natural and designed systems. The general idea of evolution is that the present arises from materials and forms of the past. Although evolution is most commonly associated with the biological theory explaining the process of descent with modification of organisms from common ancestors, evolution also describes changes in the universe. • Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions: for example, opposite forces are of the same magnitude, or off-setting

	heat, perhaps melting and recrystallizing into different kinds of rock. Describe that these reformed rock layers may be forced up again to become land surface and even mountains, and subsequently erode. ⇨ Explain how the thousands of layers of sedimentary rock can confirm the long history of the changing surface of the Earth and the changing life forms whose remains are found in successive layers, although the youngest layers are not always found on top, because of folding , breaking, and uplifting of layers. **3.3 Matter and Energy** ⇨ Explain that the sun loses energy by emitting light. Note that only a tiny fraction of that light reaches the Earth. Understand that the sun's energy arrives as light with a wide range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation. ⇨ Investigate how the temperature and acidity of a solution influences reaction rates, such as those resulting in food spoilage. ⇨Explain that many substances dissolve in water. Understand that the presence of these substances often affects the rates of reactions that are occurring in the water as compared to the same reactions occurring in the water in the absences of the substances. ⇨Explain that energy in the form of heat is almost always one of the products of an energy transformation, such as in the examples of exploding stars, biological growth, the operation of machines, and the motion of people. ⇨ Describe how electrical energy can be produced from a variety of energy sources and can be transformed into almost any other form of energy, such as light or heat. ⇨Recognize and explain that different ways of obtaining, transforming, and distributing energy have different environmental consequences.	changes occur at equal rates. Steady state, balance, and homeostasis also describe equilibrium states. Interacting units of matter tend toward equilibrium states in which the energy is distributed as randomly and uniformly as possible.

	3.4 Forces of Nature ⇨ Investigate that an unbalanced force, acting on an object, changes its speed or path of motion or both, and know that if the force always acts towards the same center as the object moves, the object's path may curve into an orbit around the center. ⇨ Describe that light waves, sound waves, and other waves move at different speeds in different materials. ⇨ Explain that human eyes respond to a narrow ranges of wavelengths of the electromagnetic spectrum. ⇨ Describe that something can be "seen" when light waves emitted or reflected by it enter the eye just as something can be "heard" when sound waves from it enter the ear.	
<u>Standard 4. The Living Environment</u> **Students begin to trace the flow of matter and energy through ecosystems. They recognize the fundamental difference between plants and animals and understand its basis at the cellular level. Students distinguish species, particularly through an examination of internal structure and functions. They use microscopes to observe cells and recognize that cells function in similar ways in all organisms.**	**4.1 Diversity of Life** ⇨Explain that similarities among organisms are found in external and internal anatomical features, including specific characteristics at the cellular level, such as the number of chromosomes. Understand that these similarities are used to classify organisms since they may be used to infer the degree of relatedness among organisms. ⇨ Describe that all organisms, including the human species, are part of and depend on two main interconnected global food webs, the ocean food web and the land food web. ⇨ Explain how in sexual reproduction, a single specialized cell from a female merges with a specialized cell from a male and this fertilized egg carries genetic information from each parent and multiples to form the complete organism. ⇨ Explain that cells continually divide to make more cells for growth and repair and that various organs and tissues function to serve the needs of cells for food, air, and waste removal. ⇨ Explain that the basic functions of organisms,	Appendix B: System, Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Systems, Order and Organization Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions. Appendix D: Science and Technology • IDENTIFY A PROBLEM OR DESIGN AN OPPORTUNITY: Students should be able to identify new problems or needs and to change and improve current technological designs.

	such as extracting energy from food and getting rid of wastes, are carried out within the cell and understand that the way in which cells function is similar in all organisms. **4.2 Interdependence of Life and Evolution** ⇨ Explain how food provides the fuel and the building material for all organisms. ⇨ Describe how plants use the energy from light to make sugars from carbon dioxide and water to produce food that can be used immediately or stored for later use. ⇨ Describe how organisms that eat plants break down the plant structures to produce the materials and energy that they need to survive, and in turn, how they are consumed by other organisms. ⇨ Understand and explain that as any population of organisms grows, it is held in check by one or more environmental factors. These factors could result in depletion of food or nesting sites and/or increase loss to increased numbers of predators or parasites. Give examples of some consequences of this. **4.3 Human Identity** ⇨ Describe how technologies having to do with food production, sanitation, and disease prevention have dramatically changed how people live and work and have resulted in changes in factors that affect the growth of human population. ⇨Explain that the amount of food energy (calories) a person requires varies with body weight, age, sex, activity level, and natural body efficiency. Understand that regular exercise is important to maintain a healthy heart/lung system, good muscle tone, and strong bone structure. ⇨Explain that viruses, bacteria, fungi, and parasites may infect the human body and interfere with normal body functions.	• PROPOSE DESIGNS AND CHOOSE BETWEEN ALTERNATIVE SOLUTIONS: Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes. • IMPLEMENT A PROPOSED SOLUTION: A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials--such as wood, metal, plastics, and textiles. Solutions can also be implemented using computer software. Appendix E: PERSONAL AND COMMUNITY HEALTH ▪ The severity of disease symptoms is dependent on many factors, such as human resistance and the virulence of the disease-producing organism. Many diseases can be prevented, controlled, or cured. Some diseases, such as cancer, result form specific body dysfunctions and cannot be transmitted. ▪ Personal choice concerning fitness and health involves multiple factors. ▪ Selection of foods and eating patterns determine nutritional balance. Nutritional balance has a direct effect on growth and development and personal well-being. ▪ Sexuality is basic to the physical, mental, and social development of humans. Students should understand that human sexuality involves biological functions, psychological motives, and cultural, ethnic, religious, and technological influences.

	Recognize that a person can catch a cold many times because there are many varieties of cold viruses that cause similar symptoms. ⇨Explain that white blood cells engulf invaders or produce antibodies that attack invaders or mark the invaders for killing by other white blood cells. Know that the antibodies produced will remain and can fight off subsequent invaders of the same kind. ⇨Explain that the environment may contain dangerous levels of substances that are harmful to human beings. Understand, therefore, that the good health of individuals requires monitoring the soil, air, and water as well as taking steps to keep them safe.	
<u>Standard 5. The Mathematical World</u> **Students apply mathematics in scientific contexts. They use mathematical ideas, such as relations between operations, symbols, statistical relationships, and the use of logical reasoning, in the representation and synthesis of data.**	**5.1 Numbers** ⇨ Demonstrate how a number line can be extended on the other side of zero to represent negative numbers and give examples of instances where this is useful. **5.2 Shapes and Symbolic Relationships** ⇨ Illustrate how lines can be parallel, perpendicular, or oblique. ⇨Demonstrate how the scale chosen for a graph or drawing determines its interpretation. **5.3 Reasoning and Uncertainty** ⇨Describe that the larger the sample, the more accurately it represents the whole. Understand, however, that any sample cab be poorly chosen and this will male it unrepresentative of the whole.	Appendix B: Constancy, Change and Measurement Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change. Appendix B: Evidence, Models, and Explanation • Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. • Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations. • Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Appendix F: Critical-Response Skills

Standard 6. Historical Perspectives		• allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. • allowing students to apply those same critical skills to their own observations, arguments, and conclusions Appendix F: Estimation and Computation Skills ▪ including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. ▪ providing experience with basic number skills and computations in meaningful contexts.
Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, that the ideas are often rejected by the scientific establishment, that the ideas sometimes spring from unexpected findings, and that the ideas grow or transform slowly through contributions of many different investigators.	**6.1 Historical Perspectives** ⇨ Understand and explain that throughout history, people have created explanations for disease. Note that some held that disease had spiritual causes, but that the most persistent biological theory over the centuries was that illness resulted from an imbalance in the body fluids. Realize that the introduction of germ theory by Louis Pasteur and others in the 19th century led to the modern understanding of how many diseases are caused by microorganisms, such as bacteria, viruses, yeasts, and parasites. ⇨Understand and explain that Louis Pasteur wanted to find out what caused milk and wine to spoil. Note that he demonstrated that spoilage and fermentation occur when microorganisms enter from the air, multiply rapidly, and produce waste products, with some desirable results, such as carbon dioxide in bread dough, and some undesirable, such as acetic acid in win. Understand that after showing that spoilage could be avoided by keeping germs out or by destroying them with heat. Pasteur investigated animal diseases and showed that	Standard #1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that make these aspects of science meaningful for the student. (See bullets under *History of Science:* • The teacher of science knows that the history of science can help students build an understanding of the scientific enterprise. • The teacher of science recognizes that some episodes in the history of science have led to major changes in our view of the world. • The teacher of science knows that science often changes by small modifications in existing knowledge, but that new scientific ideas that lead to major changes in scientific thinking can be slow to be accepted.

	microorganisms were involved in many of them. Also note that other investigators later showed that specific kinds of germs caused specific diseases. ⇨ Understand and explain that Louis Pasteur found that infection by disease organisms (germs) caused the body to build an immunity against subsequent infection by the same organisms. Realize that Pasteur then demonstrated more widely what Edward Jenner had shown for smallpox without understanding the underlying mechanism: that it was possible to produce vaccines that would induce the body to build immunity to a disease without actually causing the disease itself. ⇨Understand and describe that changes in health practices have resulted from the acceptance of the germ theory of disease. Realize that before germ theory, illness was treated bv appeals to supernatural powers or by attempts to adjust body fluids through induced vomiting, bleeding, or purging. Note that the modern approach emphasizes sanitation, the safe handling of food and water, the pasteurization of milk, quarantine, and aseptic surgical techniques to keep germs out of the body; vaccinations to strengthen the body's immune system against subsequestn infrstion by the same kind of microorganisms;and,antibiotics and other chemicals and processes to destroy microorganisms. ⇨fermentation: chemical decomposition of an organic substance	• The teacher of science knows that science has been practiced by different individuals in different cultures throughout history. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles)
<u>**Standard 7. Common Themes**</u> **Students analyze the relationships within systems. They investigate how different models can represent the same data, rates of change, cyclic changes, and changes that counterbalance one another.**	**7.1 Systems** ⇨ Explain that the output from one part of a system, which can include material, energy, or information can become the input to other parts and this feedback can serve to control what goes on in the system as a whole.	Appendix B: Constancy, Change and Measurement • Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is knowing when to use which system. • Scale includes understanding that the different

	7.2 Models and Scale ⇨ Use different models to represent the same thing, noting that the kind of model and its complexity should depend on its purpose. **7.3 Constancy and Change** ⇨ Describe how physical and biological systems tend to change until they reach equilibrium and remain that way unless their surroundings change. ⇨ Use symbolic equations to show how the quantity of something changes over time or in response to changes in other quantities.	characteristics, properties, or relationships within a system might change as its dimensions are increased or decreased. • Although most things are in the process of becoming different--changing--some properties of objects and processes are characterized by constancy, including the speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles. Appendix B: Evidence, Models and Explanation Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

STANDARDS OVERVIEW ACTIVITY: ***What Indiana's students & teachers need to know and be able to do in Science.***

	8th Grade Student Standard	**Teacher Preparation Standard**
Standard 1. The Nature of Science and Technology **Students design and carry out increasingly sophisticated investigations. They understand the reasons for isolating and controlling variables in an investigation. They realize that scientific knowledge is subject to change as new evidence arises. They examine issues in the design and use of technology, including constraints, safeguards, and trade offs.**	**1.1 The Scientific View of the World** ⇨ Recognize that and describe how scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way. ⇨ Recognize and explain that some matters cannot be examined usefully in a scientific way. ● theory: an explanation supported by substantial evidence **1.2 Scientific Inquiry** ⇨ Recognize and describe that if more than one variable changes at the same time in an experiment, the outcome of the experiment may not be attributable to any one of the variables. **1.3 The Scientific Enterprise** ⇨ Explain why accurate record keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society. ⇨ Explain why research involving human subjects requires potential subjects be fully informed about the risks and benefits associated with the research and that they have the right to refuse to participate. **1.4 Technology and Science** ⇨ Identify the constraints that must be taken into account as a new design is developed, such as gravity and the properties of the materials to be used. ⇨ Explain why technology issues are rarely simple and one-sided because contending groups may have different values and priorities. ⇨ Explain that humans help shape the future by generating knowledge, developing new technologies, and communicating ideas to others.	Standard 1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that makes these aspects of science meaningful for the student. (see detailed bullet points under 1)Knowledge: Central Concepts, 2)Knowledge: Nature of Science, and 3)Knowledge: Tools of Inquiry). Standard 4: The teacher of science understands and uses a variety of instructional strategies to encourage students' development of conceptual understanding, inquiry skills, and scientific habits of mind. (see detailed Bullet points under Knowledge). Appendix D: Science and Technology Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. Appendix B: EVIDENCE, MODELS, AND EXPLANATION Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Appendix E: SCIENCE AND TECHNOLOGY IN LOCAL, NATIONAL, AND GLOBAL CHALLENGES Science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen. Progress in science and technology can be affected by social issues and challenges. *Note: Teachers at this level have in depth preparation in one of the content areas of Appendix C. Alignment has been done using excerpts from the Appendices which apply to all teachers of science.*

<u>Standard 2. Scientific Thinking</u> **Students use computers to organize and compare information. They perform calculations and determine the appropriate units for the answers. They weigh the evidence for or against an argument, as well as the logic of the conclusion.**	**2.1 Computation and Estimation** ⇨ Estimate distances and travel times from maps and the actual size of objects from scale drawings. ⇨ Determine in what units, such as seconds, meters, grams, etc., an answer should be expressed based on the units of the inputs to the calculation. **2.2 Manipulation and Observation** ⇨ Use proportional reasoning to solve problems. ⇨ Use technological devices, such as calculators and computers, to perform calculations. ⇨Use computers to store and retrieve information in topical, alphabetical, numerical, and keyword files and create simple files of students' own devising. **2.3 Communication** ⇨ Write clear, step-by-step instructions (procedural summaries) for conducting investigations, operating something, or following a procedure. ⇨ Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions. ⇨ Use tables, charts, and graphs in making arguments and claims in, for example oral and written presentations about lab or fieldwork. **2.4 Critical Response Skills** ⇨ Explain why arguments are invalid if based on very small samples of data, biased samples, or samples for which there was no control sample. ⇨ Identify and criticize the reasoning in arguments in which fact and opinion are intermingled or the conclusions do not follow logically from the evidence given, an analogy is not apt, no mention is made of whether the control group is very much like the experimental group, or all members of a group are implied to have nearly identical characteristics that differ	Appendix F: Estimation and Computation Skills • including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. • providing experience with basic number skills and computations in meaningful contexts. Appendix F: Manipulation and Observation Skills • providing opportunities to handle common materials and tools for dealing with household and everyday technologies for making careful observations, and for handling information Appendix F: Communication Skills • providing opportunities to communicate ideas and share information with accuracy and clarity and to read and listen with understanding. Appendix F: Critical-Response Skills ▪ allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. ▪ allowing students to apply those same critical skills to their own observations, arguments, and conclusions.

<u>Standard 3. The Physical Setting</u> **Students collect and organize data to identify relationships between physical objects, events, and processes. They use logical reasoning to question their own ideas as new information challenges their conception of the natural world.**	from those of other groups. **3.1 The Universe** ⇨ Explain that large numbers of chunks of rock orbit the sun and some of this rock interacts with the Earth. **3.2 The Earth and the Processes that Shape It** ⇨ Explain that the slow movement of material within the Earth results from heat flowing out of the deep interior and the action of gravitational forces on regions of different density. ⇨Explain that the solid crust of the Earth, including both the continents and the ocean basins, consists of separate plates that ride on a denser, hot, gradually deformable layer of earth. Understand that the crust sections move very slowly, pressing against one another in some places, pulling apart in other places. Further understand that ocean-floor plates may slide under continental plates, sinking deep into the Earth, and that the surface layers of these plates may fold, forming mountain ranges. ⇨ Explain that earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Understand that under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Further understand that volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands. ⇨ Explain that everything on or anywhere near the Earth is pulled toward the Earth's center by a gravitational force. ⇨ Understand and explain that the benefits of the Earth's resources, such as fresh water, air, soil, and trees, are finite and can be reduced by using them wastefully or by deliberately or	Appendix B: Systems Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Constancy, Change and Measurement • Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and matter in systems, and by extension in the universe, remains the same. • Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change <u>Appendix B:EVOLUTION AND EQUILIBRIUM</u> • Evolution is a series of changes, some gradual and some sporadic, that account for the present form and function of objects, organisms, and natural and designed systems. The general idea of evolution is that the present arises from materials and forms of the past. Although evolution is most commonly associated with the biological theory explaining the process of descent with modification of organisms from common ancestors, evolution also describes changes in the universe. • Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions: for example, opposite forces are of the same magnitude, or off-setting changes occur at equal rates. Steady state, balance, and homeostasis also describe equilibrium states. Interacting units of matter tend toward equilibrium states in which the

	accidentally destroying them. ⇨ Explain that the atmosphere and the oceans have a limited capacity to absorb wastes and recycle materials naturally. **3.3 Matter and Energy** ⇨ Explain that all matter is made up of atoms which are far too small to see directly through an optical microscope. Understand that the atoms of any element are similar but are different from atoms of other elements. Further understand that atoms may stick together in well-defined molecules or may be packed together in large arrays. Also understand that different arrangements of atoms into groups comprise all substances. ⇨ Demonstrate, using drawings and models, the movement of atoms in a solid, liquid, and gaseous state. Explain that atoms and molecules are perpetually in motion. ⇨ Explain that increased temperature means that atoms have a greater average energy of motion and that most gases expand when heated. ⇨Describe how groups of elements can be classified based on similar properties, including highly reactive metals, less reactive metals, highly reactive non-metals, less reactive none-metals, and some almost completely non-reactive gases. ⇨ Explain that no matter how substances within a closed system interact with one another, or how they combine or break apart, the total mass of the system remains the same. Understand that the atomic theory explains the conservation of matter: if the number of atoms stays the same no matter how they are rearranged, then their total mass stays the same. ⇨ Explain that energy cannot be created or destroyed but only changed from one form into another. ⇨ Describe how heat can be transferred through materials by the collision of atoms, or across space by radiation, or if the material is fluid, by	energy is distributed as randomly and uniformly as possible.

	convection currents that are set up in it that aid the transfer of heat. ⇨ Identify different forms of energy that exist in nature. ● convection: heat transfer in liquids and gases by transport of matter from a region of one temperature to a region of a different temperature **3.4 Forces of Nature** ⇨ Explain that every object exerts gravitational force on every other object and that the force depends on how much mass the objects have and how far apart they are. ⇨ Explain that they sun's gravitational pull holds the Earth and other planets in their orbits, just as the planets' gravitational pull keeps their moons in orbit around them. ⇨ Investigate and explain that electric currents and magnets can exert force on each other. ⇨ Investigate and compare series and parallel circuits. ⇨ Compare the differences in power consumption in different electrical devices.	
<u>Standard 4. The Living Environment</u> **Students trace the flow of matter and energy through ecosystems. They understand that the total amount of matter remains constant and that almost all food energy has its origins in sunlight.**	**4.1 Diversity of Life** ⇨Differentiate between inherited traits, such as hair color or flower color, and acquired skills, such as manners. ⇨Describe that in some organisms, such as yeast or bacteria, all genes come from a single parent, while in those that have sexes, typically half of the genes come from each parent. ⇨Recognize and describe that new varieties of cultivated plants, such as corn and apples, and domestic animals, such as dogs and horses, have resulted from selective breeding for particular traits. ● gene: basic unit of heredity **4.2 Interdependence of Life and Evolution** ⇨ Describe how matter is transferred from one	Appendix B: System, Order and Organization Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world. Appendix B: Systems, Order and Organization Living systems also have different levels of organization--for example, cells, tissues, organs, organisms, population, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions.

	organism to another repeatedly and between organisms and their physical environment. ⇨ Explain that energy can be transferred from one form to another in living things. ⇨ Describe how animals get their energy from oxidizing their food and releasing some of this energy as heat. ⇨ Recognize and explain that small genetic differences between parents and offspring can accumulate in successive generations so that descendants are very different from their ancestors. ⇨ Describe how environmental conditions affect the survival of individual organisms and how entire species may prosper in spite of poor survivability or bad fortune of individuals. **4.3 Human Identity** ⇨ Recognize and describe that fossil evidence is consistent with the idea that human beings evolved from earlier species.	Appendix D: Science and Technology • IDENTIFY A PROBLEM OR DESIGN AN OPPORTUNITY: Students should be able to identify new problems or needs and to change and improve current technological designs. • PROPOSE DESIGNS AND CHOOSE BETWEEN ALTERNATIVE SOLUTIONS: Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes. • IMPLEMENT A PROPOSED SOLUTION: A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials--such as wood, metal, plastics, and textiles. Solutions can also be implemented using computer software.
<u>Standard 5. The Mathematical World</u> **Students apply mathematics in scientific contexts. Students use mathematical ideas, such as symbols, geometrical relationships, statistical relationships, and the use of key words and rules in logical reasoning, in the representation and synthesis of data.**	**5.1 Numbers** ⇨ Understand and explain that a number must be written with an appropriate number of significant figures (determined by the measurements from which the number is derived). **5.2 Shapes and Symbolic Relationships** ⇨Show that an equation containing a variable	Appendix B: Constancy, Change and Measurement Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions--measurement. Mathematics is essential for accurately measuring change. Appendix B: Evidence, Models, and Explanation • Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand

	may be true for just one value of the variable. ⇨Demonstrate that mathematical statements can be used to describe how one quantity changes when another changes. ⇨Illustrate how graphs can show a variety of possible relationships between two variables. ⇨Illustrate that it takes two numbers to locate a point on a map or any other two-dimensional surface. **5.3 Reasoning and Uncertainty** ⇨ Explain that a single example can never prove that something is always true, but it could prove that something is not always true. ⇨ Recognize and describe the danger of making over-generalizations when inventing a general rule based on a few observations. ⇨Explain how estimates can be based on data from similar conditions in the past or on the assumption that all the possibilities are known. ⇨ Compare the mean, median, and mode of a data set. ⇨ Explain how the comparison of data from two groups involves comparing both their middles and the spreads.	interactions allows individuals to predict changes in natural and designed systems. • Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations. • Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Appendix F: Critical-Response Skills • allowing students to respond to scientific assertions and arguments critically, deciding what to pay attention and what to ignore. • allowing students to apply those same critical skills to their own observations, arguments, and conclusions Appendix F: Estimation and Computation Skills ▪ including the use of estimation skills to have a sense of what an adequate degree of precision is in a particular situation and an understanding of the purpose of the calculation. ▪ providing experience with basic number skills and computations in meaningful contexts.
<u>Standard 6. Historical Perspectives</u> **Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they**	Þ **6.1** Understand and explain that Antoine Lavoisier's work was based on the idea that	Standard #1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that make these aspects of science meaningful for the student. (See bullets under *History of Science:*

understand that new ideas are limited by the context in which they are conceived, that the ideas are often rejected by the scientific establishment, that the ideas sometime spring from unexpected findings, and that they grow or transform slowly through the contribution of many different investigators.	when materials react with each other, many changes can take place, but that in every case that total amount of matter afterward is the same as before. Note that Lavoisier successfully tested the concept of conservation of matter by conducting a series of experiments in which he carefully measured the masses of all the substances involved in various chemical reactions, including the gases used and those given off. Þ **6.2** Understand and describe that the accidental discovery that minerals containing uranium darken photographic film, as light does, led to the discovery of radioactivity. Þ **6.3** Understand that and describe how in their laboratory in France, Marie Curie and her husband, Pierre Curie, isolated two new elements that were the source of most of the radioactivity uranium ore. Note that they named one radium because it gave off powerful, invisible rays, and the other polonium in honor of Madame Curie’s country of birth, Poland. Also note that Marie Curie was the first scientist ever to win the Nobel Prize in two different fields, in physics, shared with her husband, and later in chemistry. Þ **6.4** Describe how the discovery of radioactivity as a source of the Earth’s heat energy made it possible to understand how the Earth can be several billion years old and still have a not interior.	• The teacher of science knows that the history of science can help students build an understanding of the scientific enterprise. • The teacher of science recognizes that some episodes in the history of science have led to major changes in our view of the world. • The teacher of science knows that science often changes by small modifications in existing knowledge, but that new scientific ideas that lead to major changes in scientific thinking can be slow to be accepted. • The teacher of science knows that science has been practiced by different individuals in different cultures throughout history. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles)
<u>Standard 7. Common Themes</u> **Students analyze the parts and interactions of systems to understand internal and external relationships. They investigate rates of change, cyclical changes, and changes that counterbalance one another. They use mental and physical models to reflect upon and interpret the limitations of such models.**	**7.1 Systems** Þ Explain that a system usually has some properties that are different from those of its parts but appear because of the interaction of those parts. Þ Explain that even in some very simple systems, it may not always be possible to predict accurately the result of changing some part or connection.	Appendix B: Constancy, Change and Measurement • Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is knowing when to use which system. • Scale includes understanding that the different characteristics, properties, or relationships within a system might change as its dimensions are increased or decreased.

	7.2 Models and Scale Þ Use technology to assist in graphing and with simulations that compute and display results of changing factors in models. Þ Explain that as the complexity of any system increases, gaining an understanding of it depends on summaries, such as averages and ranges, and on descriptions of typical examples of that system. • range: the difference between the largest and the smallest value **7.3Constancy and Change** Þ Observe and describe that a system may stay the same because nothing is happening or because things are happening that counteract one another. Þ Recognize that and describe how symmetry may determine properties of many objects, such as molecules, crystals, organisms, and designed structures. Þ Illustrate how things, such as seasons or body temperature, occur in cycles.	• Although most things are in the process of becoming different--changing--some properties of objects and processes are characterized by constancy, including the speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles. Appendix B: Evidence, Models and Explanation Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

<u>Standard 1. Principles of Biology</u>

Students work with the concepts, principles, and theories that enable them to understand the living environment. They recognize that living organisms are made of cells or cell products that consist of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic forces. Students investigate, through laboratories and field work, how living things function and how they interact with one another and their environment.

1.1 Molecules and Cells

Þ Recognize that and explain how the many cells in an individual can be very different from one another, even though they are all descended from a single cell and this have essentially identical genetic instructions. Understand that different parts of the genetic instructions are used in different types of cells and are influences by the cell's environment and past history.

Þ Explain that every cell is covered by a membrane that controls what can enter and leave the cell. Recognize that in all but quite primitive cells, a complex network of proteins provides organization and shape. In addition, understand that flagella and/or cilia may allow some Protista, some Monera, and some animal cells to move.

Þ Know and describe that within the cell are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, information feedback, and movement. In addition to these basic cellular functions common to all cells, understand that most cells in multicellular organisms perform some special functions that others do not.

Þ Understand and describe that the work of the cell is carried out by the many different types of molecules it assembles, such as proteins, lipids, carbohydrates, and nucleic acids.

Þ Demonstrate that most cells function best within a narrow range of temperature and acidity. Note that extreme changes may harm cells, modifying the structure of their protein molecules and therefore, some possible functions.

Þ Show that a living cell is composed mainly of a small number of chemical elements-carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. Recognize that carbon can join to other carbon atoms in chains and rings to form large and complex molecules.

Þ Explain that complex interactions among the different kinds of molecules in the cell cause

Note: In addition to the content standards listed below, the teacher of High School Biology is responsible for all of the science content standards listed in standard 1 and outlined in Appendices A, B, D, E, F and G.

Appendix C: Fundamental Concepts:
2) Life Science

<u>THE CELL</u>

- Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules which form a variety of specialized structures that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material.

- Most cell functions involve chemical reactions. Food molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules. Both breakdown and synthesis are made possible by a large set of protein catalysts, called enzymes. The breakdown of some of the food molecules enables the cell to store energy in specific chemicals that are used to carry out the many functions of the cell.

- Cells store and use information to guide their functions. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires.

- Cell functions are regulated. Regulation occurs both through changes in the activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell growth and division.

- Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment. This process of

	distinct cycles of activities, such as growth and division. Note that cell behavior can also be affected by molecules from other parts of the organism, such as hormones. Þ Understand and describe that all growth and development is a consequence of an increase in cell number, cell size, and/or cell products. Explain that cellular differentiation results from gene expression and/or environmental influence. Differentiate between mitosis and meiosis. Þ Recognize and describe that both living and non-living things are composed of compounds, which are themselves made up of elements joined by energy-containing bonds, such as those in ATP. Þ Recognize and explain that macromolecules such as lipids contain high energy bonds as well. **1.2 Developmental and Organismal Biology** Þ Describe that through biogenesis all organisms begin their life cycles as a single cell and that in multicellular organisms, successive generations of embryonic cells form by cell division. Þ Compare and contrast the form and function of prokaryotic and eukaryotic cells. Þ Explain that some structures in the modern eukaryotic cell developed from early prokaryotes, such as mitochondria, and in plants, chloroplasts. Þ Recognize and explain that communication and/or interaction are required between cells to coordinate their diverse activities. Þ Understand and explain that, in biological systems, structure and function must be considered together. Þ Explain how higher levels of organization result from specific complexing and interactions of smaller units and that their maintenance requires a constant input of energy as well as new material. Þ Understand that and describe how the maintenance of a relatively stable internal	photosynthesis provides a vital connection between the sun and the energy needs of living systems. ▪ Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells. In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues, and organs that comprise the final organism. This differentiation is regulated through the expression of different genes. THE BEHAVIOR OF ORGANISMS ▪ Multicellular animals have nervous systems that generate behavior. Nervous systems are formed from specialized cells that conduct signals rapidly through the long cell extensions that make up nerves. The nerve cells communicate with each other by secreting specific excitatory and inhibitory molecules. In sense organs, specialized cells detect light, sound, and specific chemicals and enable animals to monitor what is going on in the world around them. ▪ Organisms have behavioral responses to internal changes and to external stimuli. Responses to external stimuli can result from interactions with the organism's own species and others, as well as environmental changes; these responses either can be innate or learned. The broad patterns of behavior exhibited by animals have evolved to ensure reproductive success. Animals often live in unpredictable environments, and so their behavior must be flexible enough to deal with uncertainty and change. Plants also respond to stimuli.

	environment is required for the continuation of life and explain how stability is challenged by changing physical, chemical, and environmental conditions, as well as the presence of disease agents. Þ Explain that the regulatory and behavioral responses of an organism to external stimuli occur in order to maintain both short- and long-term equilibrium Þ Recognize and describe that metabolism consists of the production, modification, transport, and exchange of materials that are required for the maintenance of life. Þ Recognize that and describe how the human immune system is designed to protect against microscopic organisms and foreign substances that enter from outside the body and against some cancer cells that arise within. **1.3 Genetics** ⇨ Understand and explain that the information passed from parents to offspring is transmitted by means of genes which are coded in DNA molecules. Þ Understand and explain the genetic basis for Mendel's laws of segregation and independent assortment. Þ Understand that and describe how inserting, deleting, or substituting DNA segments can alter a gene. An altered gene may be passed on to every cell that develops from it, and that the resulting features may help, harm, or have little or no effect on the offspring's success in its environment. Þ Explain that gene mutations can be caused by such things as radiation and chemicals. Understand that when they occur in sex cells, the mutations can be passed on to offspring; if they occur in other cells, they can be passed on to descendent cells only. Þ Explain that gene mutation in a cell can result in uncontrolled cell division, called cancer. Also know that exposure of cells to certain	▪ Like other aspects of an organism's biology, behaviors have evolved through natural selection. Behaviors often have an adaptive logic when viewed in terms of evolutionary principles. ▪ Behavioral biology has implications for humans, as it provides links to psychology, sociology, and anthropology. THE MOLECULAR BASIS OF HEREDITY ▪ In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism). Each DNA molecule in a cell forms a single chromosome. ▪ Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual. The fact

	chemicals and radiation increases mutations and thus increases the chance of cancer. Þ Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules and that this is virtually the same mechanism for all life forms. Þ Explain that the similarity of human DNA sequences and the resulting similarity in cell chemistry and anatomy identify human beings as a unique species, different from all others. Likewise, understand that every other species has its own characteristic DNA sequence. Þ Illustrate that the sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents. Recognize that genetic variation can occur from such processes as crossing over, jumping genes, and deletion and duplication of genes. Þ Understand that and explain how the actions of genes, patterns of inheritance, and the reproduction of cells and organisms account for the continuity of life, and give examples of how inherited characterisitics can be observed at molecular and whole-organism levels- in structure, chemistry, or behavior. **1.4 Evolution** Þ Understand and explain that molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another. Þ Describe how natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species, and some of these characteristics give individuals an advantage over others in surviving and reproducing. Understand that the advantaged offspring ,in turn, are more likely than others to survive and reproduce. Also understand that the proportion of individuals in the population that have	that the human body is formed from cells that contain two copies of each chromosome--and therefore two copies of each gene--explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next. ▪ Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism's offspring. <u>BIOLOGICAL EVOLUTION</u> ▪ Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring. ▪ The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.

	advantageous characteristics will increase. Þ Explain how natural selection leads to organisms that are well suited for survival in particular environments, and discuss how natural selection provides scientific explanation for the history of life on earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms. Þ Describe how life on earth is thought to have begun as simple, one-celled organisms about 4 billion years ago. Note that during the first 2 billion years, only single-cell microorganisms existed, but once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved. Þ Explain that evolution builds on what already exists, so the more variety there is, the more there can be in the future. Recognize, however, that evolution does not necessitate long-term progress in some set direction. Þ Explain that the degree of kinship between organisms and species can be estimated from the similarity of their DNA sequences, which often closely matches their classification based on anatomical similarities. Know that amino acid similarities also provide clues to this kinship. Trace the relationship between environmental changes and the changes in the gene pool, such as genetic drift and isolation of sub-populations. **1.5 Ecology** Þ Explain that the amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dean organic materials. Recognize, therefore, that human activities and technology can change the flow and reduce the fertility of the land. Þ Understand and explain the significance of the introduction of species, such as zebra mussels, into American waterways, and describe the consequent harm to native species and the	▪ Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms. ▪ The millions of different species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors. ▪ Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification. THE INTERDEPENDENCE OF ORGANISMS ▪ The atoms and molecules on the earth cycle among the living and nonliving components of the biosphere. ▪ Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers. ▪ Organisms both cooperate and compete in ecosystems. The interrelationships and interdependencies of these

	environment in general. Þ Describe how ecosystems can be reasonably stable over hundreds or thousands of years. Understand that if a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one. Þ Understand and explain that like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. However, also understand that ecosystems can always change with climate changes or when one or more new species appear as a result of migration or local evolution. Þ Recognize that and describe how human beings are part of the Earth's ecosystems. Note that human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. Þ Realize and explain that at times, the environmental conditions are such that plants and marine organisms grow faster than decomposers can recycle them back to the environment. Þ Understand that layers of energy-rich organic material thus laid down have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. Further understand that by burning these fossil fuels, people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide. Þ Understand that and describe how organisms are influenced by a particular combination of living and non-living components of the environment. Þ Describe the flow of matter, nutrients, and energy within ecosystems. Þ Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of the way organisms develop within ecosystems.	organisms may generate ecosystems that are stable for hundreds or thousands of years. ▪ Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. This fundamental tension has profound effects on the interactions between organisms. ▪ Human beings live within the world's ecosystems. Increasingly, humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and if not addressed, ecosystems will be irreversibly affected. MATTER, ENERGY, AND ORGANIZATION IN LIVING SYSTEMS ▪ All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations. With death, and the cessation of energy input, living systems rapidly disintegrate. ▪ The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon-containing (organic) molecules. These molecules can be used to assemble larger molecules with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes. ▪ The chemical bonds of food molecules contain energy. Energy is released when the bonds of food molecules are broken and new compounds with lower energy bonds are formed. Cells usually store this energy temporarily in phosphate bonds of a small high-energy compound called ATP. ▪ The complexity and organization of organisms accommodates the need for obtaining, transforming, transporting, releasing, and eliminating the matter and

<u>Standard 2. Historical Perspectives of Biology</u> **Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, that these ideas are often rejected by the scientific establishment, that these ideas sometimes spring from unexpected findings, and that these ideas grow or transform slowly through the contributions of many different investigators.**	Þ Recognize and describe that a great diversity of species increases the chance that at least some living things will survive in the face of large changes in the environment. Þ Explain, with examples, that ecology studies the varieties and interactions of living things across space while evolution studies the varieties and interactions of living things across time. **2.1** Þ Explain that prior to the studies of Charles Darwin , the most widespread belief was that all known species were created at the same time and remained unchanged throughout history. Note that some scientists at the time believed that features an individual acquired during a lifetime could be passed on to its offspring, and the species could thereby gradually change to fit an environment better. Þ Explain that Darwin argued that only biologically inherited characteristics could be passed on to offspring. Note that some of these characteristics were advantageous in surviving and reproducing. Þ Understand that the offspring would also inherit and pass on those advantages, and over generations the aggregation of these inherited advantages would lead to a new species. Þ Describe that the quick success of Darwin's book *Origin of Species*, published in 1859, came from the clear and understandable argument it made, including the comparison of natural selection to the selective breeding of animals in	energy used to sustain the organism. ▪ The distribution and abundance of organisms and populations in ecosystems are limited by the availability of matter and energy and the ability of the ecosystem to recycle materials. ▪ As matter and energy flows through different levels of organization of living systems--cells, organs, organisms, communities--and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change. Standard #1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that make these aspects of science meaningful for the student. (See bullets under *History of Science:* • The teacher of science knows that the history of science can help students build an understanding of the scientific enterprise. • The teacher of science recognizes that some episodes in the history of science have led to major changes in our view of the world. • The teacher of science knows that science often changes by small modifications in existing knowledge, but that new scientific ideas that lead to major changes in scientific thinking can be slow to be accepted. • The teacher of science knows that science has been practiced by different individuals in different cultures throughout history. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current

	wide use at the time, and from the massive array of biological and fossil evidence it assembled to support the argument. Þ Explain that after the publication of *Origin of Species*, biological evolution was supported by the rediscovery of the genetics experiments of an Austrian monk, Gregor Mendel, by the identification of genes and how they are sorted in reproduction, and by the discovery that the genetic code found in DNA is the same for almost all organisms.	understanding of scientific principles. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles)

Standard 1. Principles of Chemistry **Students begin to conceptualize the general structure of the atom and the roles played by the main parts of the atom in determining the properties of materials. They investigate, through such methods as laboratory work, the nature of chemical changes and the role of energy in those changes.**	**1.1 Properties of Matter** Þ Differentiate between pure substances and mixtures based on physical properties such as density, melting point, boiling point, and solubility. Þ Determine the properties and quantities of matter such as mass, volume, temperature, density, melting point, boiling point, conductivity, solubility, color, numbers of moles, and pH (calculate pH from the hydrogen-ion concentration), and designate these properties as either extensive or intensive. Þ Recognize such indicators of chemical changes such as temperature change, the production of a gas, the production of a precipitate, or a color change. Þ Describe solutions in terms of their degree of saturation. Þ Describe solutions in appropriate concentration units (be able to calculate these units), such as molarity, percent by mass of volume, parts per million (ppm), or parts per billion (ppb). Þ Predict formulas of stable ionic compounds based on charge balance of stable ions. Þ Use appropriate nomenclature when naming compounds. Þ Use formulas and laboratory investigations to classify substances as metal or nonmetal, ionic, or molecular, acid or base, and organic or inorganic. **1.2 The Nature of Chemical Change** Þ Describe chemical reactions with balanced chemical equations.	**Note: In addition to the content standards listed below, the teacher of High School Chemistry is responsible for all of the science content standards listed in standard 1 and outlined in Appendices A, B, D, E, F and G.** **Appendix C: The Fundamental Concepts and Major Principles of Physical, Life, and Earth and Space Science** **1) Chemistry** <u>STRUCTURE OF ATOMS</u> ▪ Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together. ▪ The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element. ▪ The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart. Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars. <u>CHEMICAL REACTIONS</u> ▪ Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based

	Þ Recognize and classify reactions of various types such as oxidation-reduction. Þ Predict products of simple reaction types including acid/base, electron transfer, and precipitation. Þ Demonstrate the principle of conservation of mass through laboratory investigations. Þ Use the principle of conservation of mass to make calculations related to chemical reactions. Calculate the masses of reactants and products in chemical reaction from the mass of one of the reactants or products and the relevant atomic masses. Þ Use Avogadro's law to make mass-volume calculations for simple chemical reactions. Þ Given a chemical equation, calculate the mass, gas volume, and/or number of moles needed to produce a given gas volume, mass, and/or number of moles of product. Þ Calculate the percent composition by mass of a compound or mixture when given the formula. Þ Perform calculations that demonstrate an understanding of the relationship between molarity, volume, and number of moles of a solute in a solution. Þ Prepare a specified volume of a solution of given molarity. Þ Use titration data to calculate the concentration of an unknown solution. Þ Predict how a reaction rate will be quantitatively affected by changes of concentration. Þ Predict how changes in temperature, surface area, and the use of catalysts will qualitatively affect the rate of a reaction. Þ Use oxidation states to recognize electron transfer reactions and identify the substance(s) losing and gaining electrons in an electron transfer reaction. Þ Write a rate law using a chemical equation reaction using experimental data. Þ Recognize and describe nuclear changes.	molecules take place constantly in every cell in our bodies. ▪ Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog. ▪ A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, the burning and processing of fossil fuels, the formation of polymers, and explosions. ▪ Chemical reactions can take place in time periods ranging from the few femtoseconds (10^{-15}seconds) required for an atom to move a fraction of a chemical bond distance to geologic time (scales of billions of years). Reaction rates depend on how often the reacting atoms and molecules encounter one another, on the temperature, and on the properties--including shape--of the reacting species. ▪ Catalysts, such as metal surfaces, accelerate chemical reactions. Chemical reactions in living systems are catalyzed by protein molecules called enzymes. ▪ Stoichiometric calculations are used to predict limiting reactants, and amount of products and reactants in chemical reactions. ▪ Laboratory safety requires current knowledge of potential hazards, including those related to chemical compounds, their interactions and appropriate laboratory equipment.

	Þ Recognize the importance of chemical processes in industrial and laboratory settings, e.g., electroplating, electrolysis, the operation of voltaic cells, and such important applications as the refining of aluminum. **1.3 The Structure of Matter** Þ Describe physical changes and properties of matter through sketches and descriptions of the involved materials. Þ Describe chemical changes and reactions using sketches and descriptions of the reactants and products. Þ Explain that chemical bonds between atoms in molecules, such as H_2, CH_4, NH_3, C_2H_4, N_2, Cl2, and many large biological molecules are covalent. Þ Describe dynamic equilibrium. Þ Perform calculations that demonstrate an understanding of the gas laws. Apply the gas laws to relations between pressure, temperature, and volume of any amount of an ideal gas or any mixture of ideal gases. Þ Use kinectic molecular theory to explain changes in gas volumes, pressure, and temperature (solve problems using pV=nRT). Þ Describe the possible subatomic particles within an atom or ion. Þ Use an element's location in the Periodic Table to determine its number of valence electrons, and predict what stable ion or ions an element is likely to form in reacting with other specified elements. Þ Use the Periodic Table to compare attractions that atoms have for their electrons and explain periodic properties, such as atomic size, based on these attractions. Þ Infer and explain physical properties of substances, such as melting points, boiling points, and solubility, based on the strength of molecular attractions. Þ Describe the nature of ionic, covalent, and hydrogen bonds, and give examples of how they	<u>STRUCTURE AND PROPERTIES OF MATTER</u> ▪ Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element. ▪ An element is composed of a single type of atom. When elements are listed in order according to the number of protons (called the atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties. This "Periodic Table" is a consequence of the repeating pattern of outermost electrons and their permitted energies. ▪ Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically. ▪ The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them. ▪ Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.

	contribute to the formation of various types of compounds. Þ Describe that spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with a frequency related to the energy spacing between levels by using Planck's relationship (E=hv). 1.4 **The Nature of Energy and Change** Þ Distinguish between the concepts of temperature and heat. Þ Solve problems involving heat flow and temperature changes, using known values of specific heat and latent heat of phase change. Þ Classify chemical reactions and/or phase changes as exothermic or endothermic. Þ Describe that the energy release per gram of material is much larger in nuclear fusion or fission reactions than in chemical reactions. The change in mass (calculated by $E=mc^2$) is small but significant in nuclear reactions. ⇒Describe the role of light, heat, and electrical energies in physical, chemical and nuclear changes. Þ Calculate the amount of radioactive substance remaining after an integral number of half-lives have passed.	CONSERVATION OF ENERGY AND THE INCREASE IN DISORDER ▪ The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered. ▪ All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves. ▪ Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion. INTERACTIONS OF ENERGY AND MATTER ▪ Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter. ▪ Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength. ▪ Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.

<u>Standard 2. Historical Perspectives of Chemistry</u> **Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, students understand that new ideas are limited by the context in which they are conceived, that these ideas are often rejected by the scientific establishment, that these ideas sometimes spring from unexpected findings, and that these ideas grow or transform slowly through the contributions of many different investigators.**	**1.5 The Basic Structures and Reactions of Organic Chemicals** Þ Convert between formulas and names of common organic compounds. Þ Recognize common functional groups and polymers when given chemical formulas and names. Þ **2.1** Explain that Antoine Lavoisier invented a whole new field of science based on a theory of materials, physical laws, and quantitative methods, with the conservation of matter at its core. Recognize that he persuaded a generation of scientists that his approach accounted for the experimental results better than other chemical systems. Þ **2.2** Describe how Lavoisier's system for naming substances and describing their reactions contributed to the rapid growth of chemistry by enabling scientists everywhere to share their findings about chemical reactions with one another without ambiguity. Þ **2.3** Explain that John Dalton's modernization of the ancient Greek ideas of element, atom, compound, and molecule strengthened the new chemistry by providing physical explanations for reactions that could be expressed in quantitative terms.	▪ In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons. <u>STRUCTURE AND PROPERTIES OF MATTER</u> ▪ Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life. ▪ Organic chemistry can be described by the structure and chemical properties of hydrocarbons, functional groups and other carbon containing compounds. Standard #1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that make these aspects of science meaningful for the student. (See bullets under *History of Science:* • The teacher of science knows that the history of science can help students build an understanding of the scientific enterprise. • The teacher of science recognizes that some episodes in the history of science have led to major changes in our view of the world. • The teacher of science knows that science often changes by small modifications in existing knowledge, but that new scientific ideas that lead to major changes in scientific thinking can be slow to be accepted.

	Þ **2.4**Explain how Frederich Wohler's synthesis of the simple organic compound urea from inorganic substances made it clear that living organisms carry out chemical processes not fundamentally different from inorganic chemical processes. Describe how this discovery let to the development of the huge field of organic chemistry, the industries based on it, and eventually to the field of biochemistry. Þ **2.5**Explain how Arrhenius's discovery of the nature of ionic solutions contributed to the understanding of a broad class of chemical reactions. Þ **2.6**Explain that the application of the laws of quantum mechanics to chemistry by Linus Pauling and others made possible an understanding of chemical reactions on the atomic level. Þ **2.7**Describe how the discovery of the structure of DNA by James D. Watson and Francis Crick made it possible to interpret the genetic code on the basis of a sequence of "letters."	• The teacher of science knows that science has been practiced by different individuals in different cultures throughout history. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles.)

STANDARDS OVERVIEW ACTIVITY: ***What Indiana's students & teachers need to know and be able to do in Science.***

High School Earth & Space Science **Teacher Preparation Standard**

Standard 1: Principles of Earth and Space Science **Students investigate, through laboratory and fieldwork, the universe, the Earth, and the processes that shape the Earth. They understand that the Earth operates as a collection of interconnected systems that may be changing or may be in equilibrium. Students connect the concepts of energy, matter conservation, and gravitation to the Earth, solar system, and universe. Students utilize knowledge of the materials and processes of the Earth, planets and stars in the context of the scales of time and size.**	**1.1 The Universe** Þ Understand and discuss the nebular theory concerning the formation of solar systems. Include in the discussion the roles of planetesimals and protoplanets. Þ Differentiate between the different types of stars found on the Hertzsprung-Russell Diagram. Þ Compare and conrast the evolution of stars of different masses. Understand and discuss the basics of the fusion processes that are the source of energy of stars. Þ Compare and contrast the differences in size, temperature, and age between our sun and other stars. Þ Describe Hubble's law. Identify and understand that the "Big Bang" theory is the most widely accepted theory explaining the formation of the universe. Þ Understand and explain the relationship between planetary systems, stars, multiple-star systems, star clusters, galaxies, and galactic groups in the universe. Þ Discuss how manned and unmanned space vehicles can be used to increase our knowledge and understanding of the universe. Þ Describe the characteristics and motions of the various kinds of objects in our solar system, including planets, satellites, comets, and asteroids. Explain that Kepler's laws determine the orbits of the planets. Þ Discuss the role of sophisticated technology, such as telescopes, computers, space probes, and particle accelerators, in making computer simulations and mathematical models in order to form a scientific account of the universe. Þ Recognize and explain that the concept of conservation of energy is at the heart of advances in fields as diverse as the study of nuclear particles and the study of the origin of the universe.	**Note: In addition to the content standards listed below, the teacher of High School Earth $ Space Science is responsible for all of the science content standards listed in standard 1 and outlined in Appendices A, B, D, E, F and G.** **Appendix C: The Fundamental Concepts and Major Principles of Physical, Life, and Earth and Space Science** **3) Earth and Space Science** <u>THE ORIGIN AND EVOLUTION OF THE UNIVERSE</u> • The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since. • Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe. • Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.

	1.2 The Earth Þ Recognize and describe that the earth sciences address planet-wide interacting systems, including the oceans, the air, the solid earth, and life on Earth, as well as interactions with the Solar System. Þ Examine the structure, composition, and function of the Earth's atmosphere. Include the role of living organisms in the cycling of atmospheric gases. Þ Describe the role of photosynthetic plants in changing the Earth's atmosphere. Þ Explain the importance of heat transfer between and within the atmosphere, land masses, and oceans. Þ Understand and explain the role of differential heating and the role of the Earth's rotation on the movement of air around the planet. Þ Understand and describe the origin, life cycle, behavior, and prediction of weather systems. Þ Investigate the causes of severe weather, and propose appropriate safety measures that can be taken in the event of severe weather. Þ Describe the development and dynamics of climatic changes over time, such as the cycles of glaciation. Þ Demonstrate the possible effects of atmospheric changes brought on by things such as acid rain, smoke, volcanic dust, greenhouse gases, and ozone depletion. Þ Identify and discuss the effects of gravity on the waters of the Earth. Include both the flow of streams and the movement of tides. Þ Describe the relationship among ground water, surface water, and glacial systems. Þ Identify the various processes that are involved in the water cycle. Þ Compare the properties of rocks and minerals and their uses.	THE ORIGIN AND EVOLUTION OF THE EARTH SYSTEM • The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today. • Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed. • Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years. • Evidence for one-celled forms of life--the bacteria--extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of the earth's atmosphere, which did not originally contain oxygen. ENERGY IN THE EARTH SYSTEM ▪ Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the earth's original formation. ▪ The outward transfer of earth's internal heat drives convection circulation in the mantle that propels the plates comprising earth's surface across the face of the globe.

	1.3 Processes that Shape the Earth Þ Explain motions, transformations, and locations of materials in the Earth's lithosphere and interior. For example, describe the movement of the plates that make up the crust of the earth and the resulting formation of earthquakes, volcanoes, trenches, and mountains. Þ Understand and discuss continental drift, sea-floor spreading, and plate tectonics. Include evidence that supports the movement of the plates, such as magnetic stripes on the ocean floor, fossil evidence on separate continents, and the continuity of geological features. Þ Investigate and discuss the origin of various landforms, such as mountains and rivers, and how they affect and are affected by human activities. Þ Differentiate among the processes of weathering, erosion, transportation of materials, deposition, and soil formation. Þ Illustrate the various processes that are involved in the rock cycle, and discuss how the total amount of material stays the same through formation, weathering, sedimentation, and reformation. Þ Discuss geologic evidence, including fossils and radioactive dating, in relation to the Earth's past. Þ Recognize and explain that in geologic change, the present arises from the materials of the past in ways that can be explained according to the same physical and chemical laws.	▪ Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. ▪ Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans. <u>GEOCHEMICAL CYCLES</u> ▪ The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles. ▪ Movement of matter between reservoirs is driven by the earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.
<u>Standard 2. Historical Perspectives of Earth and Space Science</u> **Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they**	**2.1** Þ Understand and explain that Claudius Ptolemy, an astronomer living in the second century A.D., devised a powerful mathematical model of the universe based on constant motion in perfect circles and circles on circles. Further understand that with the model, he was able to	Standard #1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that make these aspects of science meaningful for the student. (See bullets under *History of Science:* • The teacher of science knows that the history of science can help students build an understanding of the scientific enterprise.

understand that new ideas are limited by the context in which they are conceived, that the ideas are often rejected by the scientific establishment, that the ideas sometimes spring from unexpected findings, and that the ideas grow or transform slowly through the contributions of many different investigators.	predict the motions of the sun, moon, and stars, and even of the irregular "wandering stars" now called planets. Þ Understand that and describe how in the 16th century the Polish astronomer Nicholas Copernicus suggested that all those same motions outlined by Ptolemy could be explained by imaging that the Earth was turning on its axis once a day and orbiting around the sun once a year. Note that this explanation was rejected by nearly everyone because it violated common sense and required the universe to be unbelievably large. Also understand that Copernicus' ideas flew in the face of belief, universally held at the time, that the Earth was at the center of the universe. Þ Understand that and describe how Johannes Kepler, a German astronomer who lived at about the same time as Galileo, used the unprecedented precise observational data of the Danish astronomer Tycho Brahe. Know that Kepler showed mathematically that Copernicus's idea of a sun-centered system worked better than any other system if uniform circular motion was replaced with variable-speed, but predictable, motion along off-center ellipses. Þ Explain that by using the newly invented telescope to study the sky, Galileo made many discoveries that supported the ideas of Copernicus. Recognize that it was Galileo who found the moons of Jupiter, sunspots, craters and mountains on the moon, the phases of Venus, and many more stars than were visible to the unaided eye. Þ Explain that the idea, that the Earth might be vastly older than most people believed, made little headway in science until the work of Lyell and Hutton. Þ Describe that early in the 20th century the German scientist, Alfred Wegener, reintroduced the idea of moving continents, adding such evidence as the underwater shapes of the	• The teacher of science recognizes that some episodes in the history of science have led to major changes in our view of the world. • The teacher of science knows that science often changes by small modifications in existing knowledge, but that new scientific ideas that lead to major changes in scientific thinking can be slow to be accepted. • The teacher of science knows that science has been practiced by different individuals in different cultures throughout history. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles.)

	continents, the similarity of life forms and land forms in corresponding parts of Africa and South America, and the increasing separation of Greenland and Europe. Also know that very few contemporary scientists adopted his theory because Wegener was unable to propose a plausible mechanism for motion. Þ Explain that the theory of plate tectonics was finally accepted by the scientific community in the 1960s when further evidence had accumulated in support of it. Understand that the theory was seen to provide an explanation for a diverse array of seemingly unrelated phenomena, and there was a scientifically sound physical explanation of how such movement could occur.	

<u>STANDARDS OVERVIEW ACTIVITY:</u> ***What Indiana's students & teachers need to know and be able to do in <u>Science.</u>***

High School Environmental Science, Advanced **Teacher Preparation Standard**

<u>Standard 1. Principles of Environmental Science</u> **Students investigate, through laboratory and fieldwork, the concepts of environmental systems, populations, natural resources, and environmental hazards.**	**1.1 Environmental Systems** Þ Know and describe how ecosystems can be reasonably stable over hundreds or thousands of years; such as, the ecosystem of the Great Plains prior to the advent of the horse in Native American Plains societies, from then until the advent of agriculture, and well into the present. Þ Understand and describe that if a disaster, such as a flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one. Þ Understand and explain that ecosystems have cyclic fluctuations, such as seasonal changes or changes in population, as a result of migrations. Þ Understand and explain that human beings are part of the Earth's ecosystems, and give examples of how human activities can, deliberately or inadvertently, alter ecosystems. Þ Explain how the size and rate of growth of the human population in any location is affected by economic, political, religious, technological, and environmental factors, some of which are influenced by the size and rate of growth of the population. Þ Describe and give examples about how the decisions of one generation both provide and limit the range of possibilities open to the next generation. Þ Recognize and explain that in evolutionary change, the present arises from the materials of the past and in ways that can be explained, such as the formation of soil from rocks and dead organic material. Þ Recognize and describe the difference between systems in equilibrium and systems in disequilibrium. Þ Diagram the cycling of carbon, nitrogen, phosphorous, and water. Þ Identify and measure biological, chemical,	**Note: In addition to the content standards listed below, the teacher of High School Environmental Science is responsible for all of the science content standards listed in Standard 1 and outlined in Appendices A, B, D, E, F and G. Teachers are expected to meet the content standards from Appendix C for either Life Science <u>or</u> Earth & Space Science. Listed below are subsections from these standards that align with this discipline** <u>Appendix E: POPULATION GROWTH</u> ▪ Populations grow or decline through the combined effects of births and deaths, and through emigration and immigration. Populations can increase through linear or exponential growth, with effects on resource use and environmental pollution. ▪ Various factors influence birth rates and fertility rates, such as average levels of affluence and education, importance of children in the labor force, education and employment of women, infant mortality rates, costs of raising children, availability and reliability of birth control methods, and religious beliefs and cultural norms that influence personal decisions about family size. ▪ Populations can reach limits to growth. Carrying capacity is the maximum number of individuals that can be supported in a given environment. The limitation is not the availability of space, but the number of people in relation to resources and the capacity of earth systems to support human beings. Changes in technology can cause significant changes, either positive or negative, in carrying capacity. <u>Appendix E:NATURAL RESOURCES</u> ▪ Human populations use resources in the environment in order to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations. ▪ The earth does not have infinite resources; increasing human consumption places severe stress on the natural

	and physical factors within an ecosystem. Þ Locate, identify, and explain the role of the major earth biomes and discuss how the abiotic and biotic factors interact within these ecosystems. Þ Explain the process of succession, both primary and secondary, in terrestrial and aquatic ecosystems. **1.2 Flow of Matter and Energy** Þ Understand and describe how layers of energy rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. Recognize that by burning these fossil fuels, people are passing stored energy back into the environment as heat and releasing large amounts of carbon dioxide. Þ Recognize and explain that the amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle organic materials from the remains of dead organisms. Þ Describe how the chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. Þ Cite examples of how all fuels have advantages and disadvantages that society must question when considering the trade-offs among them, such as how energy use contributes to the rising standard of living in the industrially developing nations. However, explain that this energy use also leads to more rapid depletion of the Earth's energy resources and to environmental risks associated with the use of fossil and nuclear fuels. Þ Describe how decisions to slow the depletion of energy sources through efficient technology can be made at many levels, from personal to national, and they always involve trade-offs of economic costs and social values. Þ Illustrate the flow of energy through various	processes that renew some resources, and it depletes those resources that cannot be renewed. ▪ Humans use many natural systems as resources. Natural systems have the capacity to reuse waste, but that capacity is limited. Natural systems can change to an extent that exceeds the limits of organisms to adapt naturally or humans to adapt technologically. <u>Appendix E: ENVIRONMENTAL QUALITY</u> ▪ Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans. ▪ Materials from human societies affect both physical and chemical cycles of the earth. ▪ Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, over consumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and the different ways humans view the earth. <u>Appendix C: GEOCHEMICAL CYCLES</u> ▪ The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles. ▪ Movement of matter between reservoirs is driven by the earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.

	trophic levels of food chains and food webs within an ecosystem. Describe how each link in a food web stores some energy in newly made structures and how much of the energy is dissipated into the environment as heat. Understand that a continual input of energy from sunlight is needed to keep the process going. **1.3 Populations** Þ Demonstrate and explain how the factors, such as birth rate, death rate, and migration rate, determine growth rates of populations. Þ Demonstrate how resources, such as food supply, influence populations. **1.4 Natural Resources** Þ Differentiate between renewable and non-renewable resources, and compare and contrast the pros and cons of using non-renewable resources. Þ Demonstrate a knowledge of the distribution of natural resources in the U.S. and the world, and explain how natural resources influence relationships among nations. Þ Recognize and describe the role of natural resources in providing the raw materials for an industrial society. Þ Give examples of the various forms and uses of fossil fuels and nuclear energy in our society. Þ Recognize and describe alternative sources of energy provided by water, the atmosphere, and the sun. Þ Identify specific tools and technologies used to adapt and alter environments and natural resources in order to meet human physical and cultural needs. Þ Understand and describe the concept of integrated natural resource management and the values of managing natural resources as an ecological unit. Þ Understand and describe the concept and the importance of natural and human recycling in conserving our natural resources.	

	Þ Recognize and describe important environmental legislation, such as the Clean Air and Clean Water Act. **1.5 Environmental Hazards** Þ Describe how agricultural technology requires trade-offs between increased production and environmental harm and between efficient production and social values. Þ Understand and explain that waste management includes considerations of quantity, safety, degradability, and cost. Understand also that waste management requires social and technological innovations because waste-disposal problems are political and economic as well as technical. Þ Understand and describe how nuclear reactions release energy without the combustion products of burning fuels, but that the radioactivity of fuels and by-products poses other risks which may last for thousands of years. Þ Identify natural Earth hazards, such as earthquakes and hurricanes, and identify the regions in which they occur as well as the short-term and long-term effects on the environment and on people. Þ Differentiate between natural pollution and pollution caused by humans and give examples of each. Þ Compare and contrast the beneficial and harmful effects of an environmental stressor , such as herbicides and pesticides, on plants and animals. Give examples of secondary effects on other environmental components.	Appendix E: NATURAL AND HUMAN-INDUCED HAZARDS • Normal adjustments of earth may be hazardous for humans. Humans live at the interface between the atmosphere driven by solar energy and the upper mantle where convection creates changes in the earth's solid crust. As societies have grown, become stable, and come to value aspects of the environment, vulnerability to natural processes of change has increased. • Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change. • Some hazards, such as earthquakes, volcanic eruptions, and severe weather, are rapid and spectacular. But there are slow and progressive changes that also result in problems for individuals and societies. For example, change in stream channel position, erosion of bridge foundations, sedimentation in lakes and harbors, coastal erosions, and continuing erosion and wasting of soil and landscapes can all negatively affect society. • Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards--ranging from those with minor risk to a few people to major catastrophes with major risk to many people. The scale of events and the accuracy with which scientists and engineers can (and cannot) predict events are important considerations.

<u>Standard 2. Historical Perspectives of Environmental Science</u> **Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, that the ideas are often rejected by the scientific establishment, that the ideas sometimes spring from unexpected findings, and that the ideas grow or transform slowly through the contributions of many different investigators**	**2.1** Þ Explain that Rachel Carson's book, *Silent Spring*, explained how pesticides were causing serious pollution and killing many organisms. Understand that it was the first time anyone had publicly shown how poisons affect anything in nature. Note in particular that the book detailed how the pesticide DDT had gotten into the food chain. Understand that as a result of *Silent Spring*, there are now hundreds of national, state, and local laws that regulate pesticides. Þ explain that Henry Cowles found the Indiana Dunes and Lake Michigan shoreline area a natural laboratory for developing important principles of plant succession.	Standard #1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that make these aspects of science meaningful for the student. (See bullets under *History of Science:* • The teacher of science knows that the history of science can help students build an understanding of the scientific enterprise. • The teacher of science recognizes that some episodes in the history of science have led to major changes in our view of the world. • The teacher of science knows that science often changes by small modifications in existing knowledge, but that new scientific ideas that lead to major changes in scientific thinking can be slow to be accepted. • The teacher of science knows that science has been practiced by different individuals in different cultures throughout history. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles.)

<u>STANDARDS OVERVIEW ACTIVITY</u>: ***What Indiana's students & teachers need to know and be able to do in <u>Science.</u>***

High School Integrated Chemistry-Physics Teacher Preparation Standard

<u>Standard 1. Principles of Integrated Chemistry- Physics</u> **Students begin to conceptualize the general architecture of the atom and the roles played by the main constituents of the atom in determining the properties of materials. They investigate, using such methods as laboratory work, the different properties of matter. They investigate the concepts of relative motion, the action/reaction principle, wave behavior, and the interaction of matter and energy.**	**1.1 Structure and Properties of Matter** Þ Understand and explain that atoms have a positive nucleus (consisting of relatively massive positive protons and neutral neutrons) surrounded by negative electrons of much smaller mass, some of which may be lost, gained, or shared when interacting with other atoms. Þ Realize that and explain how a neutral atom's atomic number and mass number can be used to determine the number of protons, neutrons, and electrons that make up an atom. Þ Understand, and give examples to show, that isotopes of the same element have the same numbers of protons and electrons but differ in the numbers of neutrons. Þ Know and explain that physical properties can be used to differentiate among pure substances, solutions, and heterogeneous mixtures. **1.2 Changes in Matter** Þ Distinguish among chemical and physical changes in matter by identifying characteristics of these changes. Þ Understand and explain how an atom can acquire an unbalanced electrical charge by gaining or losing electrons. Þ Identify the substances gaining and losing electrons in simple oxidation-reduction reactions. Þ Know and explain that the nucleus of a radioactive isotope is unstable and may spontaneously decay, emitting particles and/or electromagnetic radiation. Þ Show how the predictability of the nuclei decay rate allows radioactivity to be used for estimating the age of materials that contain radioactive substances. Þ Understand that the Periodic Table is a listing	**Note: In addition to the content standards listed below, the teacher of High School Integrated Chemistry Physics is responsible for all of the science content standards listed in standard 1 and outlined in Appendices A, B, D, E, F and G.** ***NOTE: Alignment has been done with the Physical Science Standards. Teachers who hold only a Chemistry or Physics license would need additional preparation.*** **Appendix C: The Fundamental Concepts and Major Principles of Physical, Life, and Earth and Space Science** **1) Physical Science** <u>STRUCTURE AND PROPERTIES OF MATTER</u> ▪ Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element. ▪ An element is composed of a single type of atom. When elements are listed in order according to the number of protons (called the atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties. This "Periodic Table" is a consequence of the repeating pattern of outermost electrons and their permitted energies. ▪ Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically. ▪ The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.

	of elements arranged by increasing atomic number, and use it to predict whether a selected atom would gain, lose, or share electrons as it interacts with other selected atoms. Þ Understand and give examples to show that an enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules. Þ Realize and explain that because mass is conserved in chemical reactions, balanced chemical equations must be used to show that atoms are conserved. Þ Explain that the rate of reactions among atoms and molecules depends on how often they encounter one another, which is in turn affected by the concentrations, pressures, and temperatures of the reacting materials. Þ Understand and explain that catalysts are highly effective in encouraging the interaction of other atoms and molecules. **1.3 Energy Transformations** Þ Understand and explain that whenever the amount of energy in one place or form diminishes, the amount in the other places or forms increases by the same amount. Þ Explain that heat energy in a material consists of the disordered motions of its atoms or molecules. Þ Know and explain that transformations of energy usually transform some energy into the form of heat, which dissipates by radiation or conduction into cooler surroundings. Þ Recognize and describe the heat transfer associated with a chemical reaction or a phase change as either exothermic or endothermic, and understand the significance of the distinction. Þ Understand and explain that the energy released whenever heavy nuclei split or light nuclei combine is roughly a million times greater than the energy absorbed or released in a chemical reaction. ($E= mc^2$)	▪ Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart. ▪ Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life. <u>CHEMICAL REACTIONS</u> ▪ Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies. ▪ Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog. ▪ A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, the burning and processing of fossil fuels, the formation of polymers, and explosions. ▪ Chemical reactions can take place in time periods ranging from the few femtoseconds (10^{-15}seconds) required for an atom to move a fraction of a chemical bond distance to geologic time (scales of billions of years). Reaction rates depend on how often the reacting atoms and molecules encounter one another, on the temperature, and on the

Þ Realize and explain that the energy in a system is the sum of both potential energy and kinetic energy.

1.4 Motion

Þ Understand and explain that the change in motion of an object (acceleration) is proportional to the net force applied to the object and inversely proportional to the object’s mass. ($a=F/m$)

Þ Recognize and explain that whenever one object exerts a force on another, an equal and opposite force is exerted back on it by the other object.

Þ Understand and explain that the motion of an object is described by its position, velocity, and acceleration.

Þ Recognize and explain that waves are described by the velocity, wavelength, frequency or period and amplitude.

Þ Understand and explain that waves can superpose on one another, bend around corners, reflect off surfaces, be absorbed by materials they enter, and change direction when entering a new material.

Þ Realize and explain that all motion is relative to whatever frame of reference is chosen, for there is no absolute motionless frame from which to judge all motion.

1.5 Forces of Nature

Þ Recognize and describe that gravitational force is an attraction between masses and that the strength of the force is proportional to the masses and decreases rapidly as the square of the distance between the masses increases. ($F= G ((m_1m_2)\_/r^2)$)

Þ Realize and explain that electromagnetic forces acting within and between atoms are vastly stronger than the gravitational forces acting between atoms.

Þ Understand and explain that at the atomic level, electric forces between oppositely charged

properties--including shape--of the reacting species.

- Catalysts, such as metal surfaces, accelerate chemical reactions. Chemical reactions in living systems are catalyzed by protein molecules called enzymes.

CONSERVATION OF ENERGY AND THE INCREASE IN DISORDER

- The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered.

- All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves.

- Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion.

- Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels.

MOTIONS AND FORCES

- Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship $F = ma$, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

	electrons and protons hold atoms and molecules together and thus, are involved in all chemical reactions. Þ Understand and explain that in materials, there are usually equal proportions of positive and negative charges, making the materials as a whole electrically neutral. However, also know that a very small excess or deficit of negative charges will produce noticeable electric forces. Þ Realize and explain that moving electric charges produce magnetic forces, and moving magnets produce electric forces.	▪ Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them. ▪ Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them. ▪ The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them. ▪ Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules. ▪ Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators.
<u>Standard 2. Historical Perspectives of Integrated Chemistry-Physics</u> **Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, that the ideas are often rejected by the scientific establishment, that the ideas sometimes spring from unexpected findings, and that the ideas grow or transform slowly through the contributions of many different investigators.**	**2.1** Þ Explain that Antoine Lavoisier invented a whole new field of science based on a theory of materials, physical laws, and quantitative methods, with the conservation of matter at its core. Recognize that he persuaded a generation of scientists that his approach accounted for the experimental results better than other chemical systems. Þ Describe how Lavoisier's system for naming substances and describing their reactions contributed to the rapid growth of chemistry by enabling scientists everywhere to share their findings about chemical reactions with one another without ambiguity.	Standard #1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that make these aspects of science meaningful for the student. (See bullets under *History of Science:* • The teacher of science knows that the history of science can help students build an understanding of the scientific enterprise.

	Þ Explain that John Dalton's modernization of the ancient Greek ideas of element, atom, compound, and molecule strengthened the new chemistry by providing physical explanations for reactions that could be expressed in quantitative terms. Þ Explain that Isaac Newton created a unified view of force and motion in which motion everywhere in the universe can be explained by the same few rules. Note that his mathematical analysis of gravitational force and motion showed that planetary orbits had to be the very ellipses that Johannes Kepler had demonstrated two generations earlier. Þ Describe that Newton's system was based on the concepts of mass, forces, and acceleration, his three laws of motion relating them, and a physical law stating that the force of gravity between any two objects in the universe depends only upon their masses and the distance between them. Þ Explain that the Newtonian model made it possible to account for such diverse phenomena as tides, the orbits of the planets and moons, the motion of falling objects, and the Earth's equatorial bulge. Þ Describe that among the surprising ideas of Albert Einstein's special relativity is that nothing can travel faster than the speed of light, which is the same for all observers no matter how they or the light source happen to be moving. Þ Explain that the special theory of relativity is best known for stating that any form of energy has mass, and that matter itself is a form of energy. ($E=mc^2$) Þ Describe that general relativity theory pictures Newton's gravitational force as a distortion of space and time. Þ Explain that Marie and Pierre Curie made radium available to researchers all over the world, increasing the study of radioactivity and	• The teacher of science recognizes that some episodes in the history of science have led to major changes in our view of the world. • The teacher of science knows that science often changes by small modifications in existing knowledge, but that new scientific ideas that lead to major changes in scientific thinking can be slow to be accepted. • The teacher of science knows that science has been practiced by different individuals in different cultures throughout history. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles.)

	leading to the realization that one kind of atom may change into another kind, and so must be made up of smaller parts. Note that these parts were demonstrated by Ernest Rutherford, Niels Bohr, and other scientists to be a small, dense nucleus that contains protons and neutrons and is surrounded by a cloud of electrons. Þ Explain that Rutherford and his colleagues discovered that the heavy radioactive element uranium spontaneously splits itself into a slightly lighter nucleus and a very light helium nucleus. Þ Describe that later, Austrian and German scientists showed that when uranium is struck by neutrons, it splits into two nearly equal parts plus one or two extra neutrons. Note that Lise Meitner, an Austrian physicist, was the first to point out that if these fragments added up to a less mass than the original uranium nucleus, then Einstein's special relativity theory predicted that a large amount of energy would be released. Also note that Enrico Fermi, and Italian working with colleagues in the United States, showed that the extra neutrons trigger more fissions and so create a sustained chain reaction in which a prodigious amount of energy is given off.	

STANDARDS OVERVIEW ACTIVITY: ***What Indiana's students & teachers need to know and be able to do in Science.***

	High School Physics	**Teacher Preparation Standard**
Standard 1. Principles of Physics **Students recognize the nature and scope of physics, including its relationship to other sciences and its ability to describe the natural world. Students learn how physics describes the natural world, using quantities such as velocity, acceleration, force, energy, momentum, and charge. Through experimentation and analysis, students develop skills that enable them to understand the physical environment. They learn to make predictions about natural phenomena by using physical laws to calculate or estimate these quantities. Students learn that this description of nature can be applied to diverse phenomena at scales ranging from the subatomic to the structure of the universe, and including every day events. Students learn how the ideas they study in physics can be used in concert with the ideas of the other sciences. They also learn how physics can help to promote new technologies. Students will be able to communicate what they have learned orally, mathematically, using diagrams and writing.**	**1.1 The Properties of Matter** Þ Describe matter in terms of fundamental constituents, and be able to differentiate among these constituents. Þ Measure or determine the physical quantities including mass, charge, pressure, volume, temperature, and density of an object or unknown sample. Þ Describe and apply the kinetic molecular theory to the states of matter. Þ Employ correct units in describing common physical quantities. **1.2 The Relationships between Motion and Force** Þ Use appropriate vector and scalar quantities to solve kinematics and dynamics problems in one and two dimensions. Þ Describe and measure motion in terms of position, time, and the derived quantities of velocity and acceleration. Þ Use Newton's Laws (e.g., $F=ma$) together with the kinematic equations to predict the motion of an object. Þ Describe the nature of centripetal force and	**Note: In addition to the content standards listed below, the teacher of High School Physics is responsible for all of the science content standards listed in standard 1 and outlined in Appendices A, B, D, E, F and G.** **Appendix C: The Fundamental Concepts and Major Principles of Physical, Life, and Earth and Space Science** **1) Physics** MEASUREMENT AND PROPERTIES OF MATTER • Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. • Objects can be described in terms of six observable and measurable quantities: mass, charge, pressure, volume, temperature, and density. Appropriate laboratory tools and instruments can be used to measure or determine these quantities for a given sample. • The measurable physical quantities of an object and interactions with its surroundings must be described using correct and appropriate units. The base (fundamental) units in the metric (SI) system are the kilogram, second, meter, Kelvin, candela, Ampere, and mole. Other quantities used in physical descriptions use derived units that are combinations of base units. • Measurements differ in their precision and accuracy, but all measurement involves uncertainty. <u>MOTIONS AND FORCES</u> ▪ Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of

	centripetal acceleration (including the formula $a = v^2/r$), and use these ideas to predict the motion of an object. Þ Use the conservation of energy and conservation of momentum laws to predict, both conceptually and quantitatively, the results of the interactions between objects. Þ Demonstrate an understanding of the inverse square nature of gravitational and electrostatic forces. **1.3 The Nature of Energy** Þ Recognize energy in its different manifestations, such as kinetic ($KE = ½ mv^2$), gravitational potential ($PE = mgh$), thermal, chemical, nuclear, electromagnetic, or mechanical. Þ Use the law of conservation of energy to predict the outcome(s) of an energy transformation. Þ Use the concepts of temperature, thermal energy, transfer of thermal energy, and the mechanical equivalent of heat to predict the results of an energy transfer. Þ Explain the relation between energy (E) and power (P). Explain the definition of the unit of power, the watt. **1.4 Momentum and Energy** Þ Distinguish between the concepts of momentum (using the formula $p=mv$) and energy. Þ Describe circumstances under which each conservation law may be used. **1.5 The Nature of Electricity and Magnetism** Þ Describe the interaction between stationary charges using Coulomb's Law. Know that the force on a charged particle in an electrical field is q*E*, where E is the electric field at the position of the particle, and q is the charge of the particle. Þ Explain the concepts of electrical charge, electrical current, electrical potential, electric field, and magnetic field. Use the definitions of coulomb, the ampere, the volt, the volt/meter, and the tesla. Þ Analyze simple arrangements of electrical components in series and parallel circuits. Know that any resistive element in a DC circuit dissipates energy,	objects. The magnitude of the change in motion can be calculated using the relationship F = ma, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object. ▪ Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them. ▪ Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them. ▪ The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them. ▪ Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules. ▪ Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators. <u>INTERACTIONS OF ENERGY AND MATTER</u> ▪ Waves, including sound and seismic waves, waves

	which heats the resistor. Calculate the power (rate of energy dissipation), using the formula Power =$IV= I^2R$. Þ Describe electric and magnetic forces in terms of the field concept and the relationship between moving charges and magnetic fields. Know that the magnitude of the force on a moving particle with charge q in a magnetic field is *qvbsina*, where *v* and *B* are the magnitudes of vectors *v* and *B* and a is the angle between *v* and **B**. Þ Explain the operation of electric generators and motors in terms of Ampere's law and Faraday's law.	on water, and light waves, have energy and can transfer energy when they interact with matter. ▪ Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength. ▪ Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance. ▪ In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electron.
	1.6 The Behavior of Waves Þ Describe waves in terms of their fundamental characteristics of velocity, wavelength, frequency or period, and amplitude. Know the radio waves, light, and x-rays are different wavelength bands in the spectrum of electromagnetic waves, whose speed in a vacuum is approximately 3x108 m/s (186,000 miles/second). Þ Use the principle of superposition to describe the interference effects arising from propagation of several waves through the same medium. Þ Use the concepts of reflection, refraction, polarization, transmission, and absorption to predict the motion of waves moving through space and matter. Þ Use the concepts of wave motion to predict	OSCILLATIONS AND THE BEHAVIOR OF WAVES • Simple harmonic motions are caused by a restoring force proportional to the displacement from equilibrium and can be described by sine or cosine graphs. Simple pendulums and masses on springs are common applications of systems that can be described or approximated by simple harmonic motion. • Waves, including waves on water, sound, and light waves, transfer energy when they interact with matter. • The behavior of waves can be described by reflection, refraction, diffraction, interference,

	conceptually and quantitatively the various properties of a simple optical system. Þ Identify electromagnetic radiation as a wave phenomenon after observing refraction, reflection, and polarization of such radiation. **1.7 The Laws of Thermodynamics** Þ Understand that the temperature of an object is proportional to the average kinetic energy of the molecules in it and that the thermal energy is the sum of all the microscopic potential and kinetic energies. Þ Describe the Laws of Thermodynamics, understanding that energy is conserved, heat does not move from a cooler object to a hotter one without the application of external energy and that there is a lowest temperature, called absolute zero. Use these laws in calculations of the behavior of simple systems.	polarization, dispersion, transmission, and absorption. • The perceptions and properties associated with sound and light are determined by the characteristics of the waves that carry them. • The concepts of wave motions can be used to predict both conceptually and quantitatively the behavior of simple optical systems. <u>CONSERVATION OF ENERGY AND THE INCREASE IN DISORDER</u> ▪ The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, energy can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered. ▪ All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves. ▪ The kinetic molecular theory describes thermal energy as random motion and vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion. ▪ Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels. ▪ The laws of thermodynamics explain and predict the behavior of most thermal systems.

		▪ Atomic interaction of particles are responsible for macroscopic thermal properties of materials such as heat capacity, thermal expansion, thermal conduction, etc.
	1.8 The Nature of Atomic and Subatomic Physics Þ Describe the nuclear model of an atom in terms of mass and spatial relationships of the electrons, protons, and neutrons. Þ Explain that the nucleus, although it contains nearly all of the mass of the atom, occupies less than the proportion of the solar system occupied by the sun. Explain that the mass of a neutron or a proton is about 2,000 times greater than the mass of an electron. Þ Explain the role of the strong nuclear force in binding matter together. Þ Using the concept of binding energy per nucleon, explain why a massive nucleus that fissions into two medium-mass nuclei emits energy in the process. Þ Using the same concept, explain why two light nuclei that fuse into a more massive nucleus emit energy in the process. Þ Understand and explain the properties of radioactive materials, including half-life, types of emissions, and the relative penetrative powers of each type. Þ Describe sources and uses of radioactivity and nuclear energy.	ATOMIC AND SUBATOMIC PHYSICS ▪ Almost all of the mass of an atom is contained in the protons and neutrons in the nucleus, while the electrons in their orbits determine the size of the atom. The atom can be thought of as mainly empty space ▪ The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength. Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance. ▪ A strong nuclear force overcomes Coulomb repulsion in stable nuclei. The degree of stability is expressed as the average binding energy per nucleon. ▪ Radioactive isotopes are unstable and undergo spontaneous nuclear reactions. Some nuclei that are unstable decay by releasing alpha, beta, or gamma emissions to form more stable daughter nuclei. The speed with which these processes proceed can be described by decay rates and half lives. ▪ Because midsize nuclei are the most stable, both fusion of light nuclei or fission of large nuclei can release energy. The amount of energy released per particle involved is much greater for nuclear changes than for chemical or physical changes.

<u>Standard 2. Historical Perspectives of Physics</u> **Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, the students understand that new ideas are limited by the context in which they are conceived, that the ideas are often rejected by the scientific establishment, that these ideas sometimes spring from unexpected findings, and that the ideas grow or transfom slowly through the contributions of many different investigator.**	**2.1** Þ Explain that Isaac Newton created a unified view of force and motion in which motion everywhere in the universe can be explained by the same few rules. Note that his mathematical analysis of gravitational force and motion showed that planetary orbits had to be the very ellipses that Johannes Kepler had proposed two generations earlier. ⇒Describe how Newton's system was based on the concepts of mass, force, and acceleration, his three laws of motion relating to them, and a physical law stating that the force of gravity between any tow objects in the universe depends only upon their masses and the distance between them. Þ Explain that the Newtonian model made it possible to account for such diverse phenomena as tides, the orbits of the planets and moons, the motion of falling objects, and the Earth's equatorial bulge. Þ Describe how the Scottish physicist James Clerk Maxwell used Ampere's law and Faraday's law to predict the existence of electromagnetic waves and predict that light was just such a wave. Also understand that these predictions were confirmed by Heinrich Hertz, whose confirmations thus made possible the fields of ratio, television, and many other technologies. Þ Describe how among the surprising ideas of Albert Einstein's special relativity is that nothing can travel faster than the speed of light, which is the same for all observers no matter how they or the light source happen to be moving, and that the length of time interval is not the same for observers in relative motion. Þ Explain that the special theory of relativity ($E=mc^2$) is best known for stating that any form of energy has mass and that matter itself is a form of energy. Þ Describe how general relativity theory pictures Newton's gravitational force as a distortion of space and time. Þ Explain that Marie and Pierre Curie made radium available to researchers all over the world, increasing	Standard #1: The teacher of science understands the central concepts, tools of inquiry, and the history and nature of science in order to create learning experiences that make these aspects of science meaningful for the student. (See bullets under *History of Science:* • The teacher of science knows that the history of science can help students build an understanding of the scientific enterprise. • The teacher of science recognizes that some episodes in the history of science have led to major changes in our view of the world. • The teacher of science knows that science often changes by small modifications in existing knowledge, but that new scientific ideas that lead to major changes in scientific thinking can be slow to be accepted. • The teacher of science knows that science has been practiced by different individuals in different cultures throughout history. • The teacher of science knows that individual scientists and teams of scientists have made significant contributions to our current understanding of scientific principles.)

	the study of radioactivity and leading to the realization that one kind of atom may change into another kind, and so must be made up of smaller parts. Note that these parts were demonstrated by Rutherford, Geiger, and Marsden to be small, dense nuclei that contain protons and neutrons and are surrounded by clouds of electrons. Þ Explain that Ernest Rutherford and his colleagues discovered that the radioactive element radon spontaneously splits itself into a slightly lighter nucleus and a very light helium nucleus. Þ Describe how later, Austrian and German scientists showed that when uranium is struck by neutrons, it splits into two nearly equal parts plus two or three extra neutrons. Note that Lise Meitner, an Austrian physicist, was the first to point out that if these fragments added up to less mass than the original uranium nucleus, then Einstein's special relativity theory predicted that a large amount of energy would be released. Also note that Enrico Fermi, an Italian working with colleagues in the United States, showed that the extra neutrons trigger more fissions and so create a sustained chain reaction in which a prodigious amount of energy is given off.	